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Stage I: Sustainable Harvest of Wild Mushrooms in Northern Saskatchewan

ADF project # 20000235

February 2005

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Abstract

A three year ADF project collected baseline data characterizing mushroom (*Cantharellus cibarius* and *Tricholoma magnivelare*) ecosites in Saskatchewan. Vegetation, forest inventory, mushroom production and meteorological data were collected. The project concentrated on chanterelles mushrooms which currently offer the most potential for development in Northern Sask. Chanterelle season began as early as July 12 in 2003 and as late as early September in 2004. However, certain trends were noted:

1) Average temperatures across all sites and years in the period two weeks following harvest were 4.28°C with minimum temperatures averaging –6.8°C. This contrasted with the period from the beginning to the end of harvest in which average temperatures were 14.1°C with minimum temperatures of –0.6°C.

2) Based on a 5°C base temperature, GDD accumulation of roughly 790±70 hours coincided with the accumulation of GDD from 6 weeks prior to harvest to the peak of harvest in each of 2002, 2003 and 2004.

3) Multiple linear regression analysis using GDD + soil temperature + either soil moisture or precipitation provided the highest regression value when dates were offset between 6 – 13 weeks prior to the initiation of harvest. Thus, it appears that a combination of meteorological factors and not simply temperature are acting to induce chanterelle fruiting body appearance.

4) An accumulation of roughly 530 ± 35°C soil temperature (accumulated from 6 weeks prior to purchase) consistently coincided with the start of chanterelle purchases in each of 2002, 2003 and 2004 seasons. Longer term studies are required to determine if this trend and the 790±70 GDD could be used as a predictor of chanterelle mushroom season. The period of 6 weeks prior to initiation of harvest may be the most critical in which meteorological parameters expressed the highest correlation with yield.

Chanterelle yields varied widely between years from 0.73 kg/ha (2004) to 1.26 kg/ha (2003) to 2.71 kg/ha (2002). Calculations of chanterelle and pine mushroom yield and value per hectare will require several more years of data collection in order to more accurately determine the true value of this renewable resource.

Executive Summary

As mushroom harvesting sites in Europe and Japan become scarce, demand for North American-sourced mushrooms have markedly increased. In Saskatchewan, the wild mushroom industry has grown to a value of about $1M. The increased interest in wild mushrooms has increased the need for more information on wild mushrooms and their role in the forest ecosystem. Much of the mushroom research has been conducted on the West Coast of Canada and the United States where climatic and forest types are much different from the boreal forest. Thus, there is a strong need for the collection of baseline information on wild mushroom production in Northern Saskatchewan. This information could act as a basis for discussion and development of land use policies in Northern Saskatchewan and will be useful to mushroom harvesters, forest planners (government and industry), environmentalists and other interested parties.

In Saskatchewan, two of the commercial wild mushroom species include: chanterelles (*Cantharellus cibarius)* and pine mushrooms (*Tricholoma magnivelare*). This project: a) characterized 3 ecosites of productive mushroom areas; b) investigated key daily weather parameters which may be correlated with daily purchase volumes; c) collected yield data from more remote sites; d) evaluated over 100 stands of varying age, tree density, tree species for presence of chanterelle and pine mushrooms; e) examined techniques to avoid pest damage in pine mushrooms; f) investigated sustainable methods of pine mushroom and chanterelle harvest and g) spoke with harvesters/buyers to obtain additional guideline information.

a) All Saskatchewan sites have distinctly different vegetation than that reported for British Columbia and the Pacific Northwest regions. Our Saskatchewan sites correspond to the Boreal Plain Ecozone and are in the Mid-boreal Upland Ecoregion. They are characterized by pure stands of jack pine at density B (moderately open canopy) and stand age of approximately 70-80 years. This characterization corresponds to an **a1 lichen jP** site classification. Shrubs were only present in the <0.5m layer. The most prominent shrubs in terms of frequency and mean cover were *Vaccinium angustifolium* (blueberry) and *Arctostaphylos uva-ursi* (bearberry), each with a mean covers >2% and a frequencies of 80%. Forbs and graminoids were both low in number of species and in their cover, which is consistent with dry jack pine stands. There were only two notable species within the forbs and graminoid layer with frequency of occurrence greater than 60% - *Oryzopsis pungens* (northern rice grass) and *Maianthemum canadensis* (two-leaved Solomon's seal or wild-lily-of-the-valley). the most important among the bryophyte and lichen species recorded, in terms of both frequency of occurrence and mean cover, were the "reindeer lichens" – *Cladina mitis*, *Cladina stellaris*, and *Cladina rangiferina*. Combined, this lichen group covered nearly 60% of the bryophyte and lichen layer. All plots were underlain by Eluviated Eutric Brunisol soils, developed in stone-free, fine sandy deposits of fluvial-lacustrine or glaciofluvial origin with gentle topography. Soil textures were mostly fine sand, with minor occurrence of medium sand textures. Plot soils were typically rapidly to well-drained, with subxeric to submesic ecological moisture regimes. Nutrient regimes were consistently poor. Organic (duff) horizons were consistently thin (2-3 cm) Fibrimors. At each of 8 separate locations, soil samples were taken within chanterelle patches ("IN") and 10 m. external to the visible patches ("OUT") at each of the Ae (0-1.5 to 5 cm) and Bm (1.5 – 5 to 8 cm) horizons.

Total soil organic carbon. total sulfur. nitrogen. pH. TDS. K$^+$ and NO $^{3-}$ were examined within "IN" and "OUT" sampling areas. No significant differences were found between the "IN" and "OUT" samples. However. number of locations should be expanded in future to reduce variation.

b) Meteorological data was taken hourly from mid May to end of September for each of 3 sites in each of 2002. 2003 and 2004 and included: soil temperature at 5 cm depth. air temperature at 30 cm height. soil moisture at 5 cm depth and relative humidity at 30 cm above ground level. Since weather stations on Sites 1. 2 and 3 were located in the commercial chanterelle harvest region. correlations and multiple linear regressions based on daily and cumulative meteorological data were performed with daily purchase volumes of chanterelle mushrooms. The meteorological data was first averaged between the 3 sites in order to obtain a broad weather response over the region. Specifically tests were run to determine: A) If there is an optimum GDD base air temperature; timing of important weather parameters prior to yield response; if correlations of air or soil temperature. rainfall. soil moisture or humidity are correlated with timing and volume of chanterelle yield in 2002. 2003 and 2004. Correlations were performed between daily yield and: air temperature growing degree days (GDD) at varying base temperatures (0. 2. 5. 7. 10. 12. 15°C); humidity. rainfall. and soil moisture for the following time periods: 0 shift (i.e. correlations run when yield and meteorological data coincide according to calendar date). 2 day shift (correlations run when meteorological data are shifted by 2 days prior to the calendar date initiation of chanterelle purchase volumes). 4. 6. 8. 14. 18. 21. 28 day. 6 week. 8 week. 10 week and 12 week shifts in each of 2002. 2003 and 2004 years. Multiple regression analysis was also performed between these parameters and daily yield. B) The average and cumulative GDD air and soil temperatures at and during the critical time period prior to the initiation of chanterelle purchase volumes. C) Minimum. maximum and average temperatures for the period during and at the end of harvest in 2002. 2003 and 2004.

The initiation of the harvest season. peak. duration of the peak and end dates all differ depending on year. Chanterelle season began as early as July 12 in 2003 and as late as early September in 2004. Chanterelle season ended as late as the end of September in 2004 while minimal purchases were made after Sept. 10 in 2002. No clear trends were observed when GDD was compared based on GDD accumulation to harvest. during harvest. from the beginning of harvest to the peak and from the peak to the end of harvest in 2002. 2003 and 2004. However. several points were worthy of note: 1) Average temperatures across all sites and years in the period two weeks following harvest were 4.28°C with minimum temperatures averaging –6.8°C. This contrasted with the period from the beginning to the end of harvest in which average temperatures were 14.1°C with minimum temperatures of –0.6°C. 2) There appeared to be a trend in that based on a 5°C base temperature. GDD accumulation of roughly 790±70 hours coincided with the accumulation of GDD from 6 weeks prior to harvest to the peak of harvest in each of 2002. 2003 and 2004. 3) Altering GDD using various base temperatures of 0. 2. 5. 7. 10. 12. 15°C did not result in higher correlations with yield in either 2002. 2003 or 2004. However. except for 2003. 6 weeks prior to the start of chanterelle purchase coincided with the point of highest correlation between daily purchase yield and daily GDD. 4) Multiple linear regression analysis using GDD + soil temperature + either soil moisture or precipitation provided the highest regression value when dates were offset between 6 – 13 weeks prior to the initiation of harvest. Thus, it appears that a combination of meteorological factors and not simply temperature are acting to induce chanterelle fruiting body appearance. 5) An accumulation of roughly 530 ± 35°C soil temperature (accumulated from 6 weeks prior to purchase) consistently coincided with the start of chanterelle purchases in each of 2002, 2003 and 2004 seasons. Longer term studies are required to determine if this trend and the 790±70 GDD could be used as a predictor of chanterelle mushroom season.

It should be noted that according to literature, the Japanese matsutake fruiting typically begins soon after the advent of the fall rainy season in a ring centered around the host tree on the AMZ, when soil temperature falls below 19°C. However, in Saskatchewan, average daily soil temperatures never reached 19°C and thus, localized information related to Saskatchewan conditions is important and data based on British Columbia or Pacific Northwest weather data may not be applicable here.

c) In order to avoid competition with harvesters, yield data was collected from very remote areas---only accessible by ATV and canoe. A preliminary test indicated strip yield plots over-estimated yield per hectare and therefore, mushrooms were harvested from an entire stand. Yield in 2003 and 2004 was repeatedly collected over the season to provide a more accurate assessment of total productivity. Chanterelle yields varied widely between years from 0.73 kg/ha (2004) to 1.26 kg/ha (2003) to 2.71 kg/ha (2002). Although the 2002 harvest had the highest chanterelle mushroom yield, collection only represented the latter part of the season and thus actual yield would have been higher than reported. Pine mushroom yield was minimal at the remote location selected and alternative locations for this species may need to be explored. Calculations of chanterelle and pine mushroom yield and value per hectare will require several more years of data collection in order to more accurately determine the true value of this renewable resource.

A rapid estimation of chanterelle fruiting body yield was developed (R^2 = 87.6%). Regression analysis of chanterelle fresh weight as a function of cap and stem diameter: Cap diameter was the best predictor of fresh weight; stem diameter adds very little to the model and by itself is a very poor predictor (R^2 = 59.7%).

d) A total of 106 and 83 sites were surveyed in 2002 and 2003, respectively. Due to lack of sites in some classes, there was uneven representation for some classes. Nevertheless, in general four stand ages (<20 years, 20-40 years, 40-60 years, and >60 years), 2 densities (A/B and C/D) and 2 species (Jack Pine, Jack Pine/Black Spruce) were surveyed. A reconnaissance survey was conducted through a presence or absence of chanterelle and pine mushrooms recorded on a per stand area. A survey was conducted using a transect through the center of each stand. Once mushrooms were observed within a stand, that stand was recorded as "present" and no further sampling was conducted within that particular stand. If mushrooms were not observed on the first line transect through the center of the stand, then observations were taken on the second line back to the originating point. In 2002 and 2003, both chanterelle and pine mushrooms were observed in higher quantities in pure Jack Pine stands compared to Jack Pine/Black Spruce mixtures. Furthermore, consistently between the two years, incidence of chanterelle mushrooms were greatest in pure Jack Pine of density A-B and stand age 41-60 years. Pine mushroom productivity was lower but generally fit this trend. Notably, chanterelle and pine mushrooms were recorded in very young stands of < 20 years of age. In contrast to our study, the mushrooms in British Columbia are often associated with 60- to 200-year old lodgepole pine, western hemlock, Douglas fir, white bark pine and Subalpine fir forests. Thus, it is important to obtain specific information based on region to allow for these differences. Similar to our study, the canopy is often partially open with the timber of marginal value due to disease or poor growing conditions.

e) The maggots from the Pine mushrooms when hatched were identified to be from the genus *Drosophila*. The species could not be identified. Remay field cover (spun-bonded polypropylene) was placed over one suspected shiro in May. In spite of the cover, pine mushrooms emerging from beneath the Remay cover harboured both larvae and pupae. However, initial visual observations of these mushrooms did not indicate any evidence of insect damage and it was only upon 4 weeks of incubation at room temperature that larvae emerged.

f) Various international experts were consulted by e-mail and their responses are summarized:

- Only *Cantharellus cibarius* mushrooms of cap diameter > 2 cm should be picked.
- These mushrooms are long-lived (about 84 days) and will continue to produce spores from within 2 weeks of emergence to the end of its life stage (up to 3 months).
- From 250,000 to 100 million spores are released per mushroom.
- Best sporulation conditions are warm, dry weather conditions. Sporulation is reduced in wet, cool weather.
- In Switzerland, harvesters cannot pick between the 1st to the 10th of each month to allow time for sporulation.
- Picking fruiting bodies will decrease sporulation potential by a factor of 1,000 to 10,000.
- Chanterelles should be cut, not pulled when picking, although this has not been found to be consistently true.

In terms of Pine mushrooms, Jong (2004a) outlines: "The most valuable matsutake (Pine mushroom) are immature "buttons", which have not yet emerged from litter layers. There is real concern that raking litter layers to find the higher graded matsutake can disturb the mycelium or disrupt the humid litter layer micro-environment that allows initial development of the primordia. Recent research with American matsutake in Oregon suggests that raking can decrease subsequent production for several years. By using proper harvest techniques listed below, harvesters can get the best possible recovery of matsutake year after year.
1) Pick mushrooms one by one by hand or using special tools;
2) Do not rake or otherwise disturb the forest floor;
3) Pick only the mushrooms that reach optimal size and value;
4) Spread the caps (with spores) of mushrooms that are too old to sell or eat.
5) Do not remove or disturb litter layers where more mushrooms are continuously growing, and
6) Replace all soils and litter to their natural look after harvest.
When a mushroom is found, remove litter and soil covering only the cap, and then place a hand

around the cap and wiggle it in a circular motion. Almost all may be harvested using this hand method. In some situations, harvesters are permitted to use only narrow tools (less than 1 inch wide) such as weed poppers for prying mushroom from ground. a variety of methods are used. but most insert the tool in the soil about 1 inch from the mushroom, at a depth just below the bottom of the stem, and then pry up. It is imperative that a tool is used only when the hand method fails." In addition, special foot gear with long spiked soles may prevent excessive trampling of the lichen layers.

g) Interviews with buyers enabled the acquisition of the detailed summary of mushroom purchases on a per day basis. This information was only possible through the long-standing relationship cultivated by Gerry Ivanochko. These relationships are extremely important in providing accurate information on yield. Interviews with pickers were used to identify sites for the inventory. Cliff Jessup and Gerry Ivanochko observed mushroom production in islands of trees left after a fire. These trees were also of the <20 year range and in future, management of forests where stands are left intact could be investigated.

This project confirms the importance of acquiring data under Saskatchewan conditions since site characteristics, tree age and type are distinctly different than that reported on the west coast. Notably, both chanterelle and pine mushrooms were present in stands of < 20 years of age with greatest occurrence in pure Jack Pine stands of 41 – 60 years of A/B density. Cumulative GDD and soil temperature may provide insight into the timing of chanterelle fruiting body appearance, however, interactions between several parameters including GDD, soil temperature and moisture will likely result in the most accurate estimate. The period of 6 weeks prior to initiation of harvest may be the most critical in which meteorological parameters express the highest correlation with yield. Long term yield studies are essential for more accurate estimates of productivity and economic potential of this renewable resource.

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Stage I: Sustainable Harvest of Wild Mushrooms in Northern Saskatchewan

1.0 Introduction

As mushroom harvesting sites in Europe and Japan become scarce, demand for North American-sourced mushrooms have markedly increased. The American matsutake export the U.S. and Canada to Japan began in the mid 1970s and have increased a thousand-fold since the mid 1980s (Jong, 2004). The current yield averages 500 tons/year and represents about 15 percent of worldwide exports. According to Schlosser and Blatner (1995), wild mushroom harvesting contributed $ 40 million US in Idaho, Washington and Oregon in 1992 alone. Furthermore, it represents seasonal employment of 11,000 people/year in those regions in an average mushroom year with 4 million pounds of mushrooms collected and sold. Significantly, it provides diversified income to other segments of the forestry industry including loggers, fire crews, students, homemakers and Native American people (Arborvitae Environmental Services Ltd., 1997). Scott Redhead in his paper "Forest mushroom harvesting in Canada: past, present and future" states that wild mushrooms are highly seasonal, very dependent upon weather conditions, and can be unreliable but also as one of the last frontiers for entrepreneurs interested in natural resources.

According to Shung-Chang Jong (2004), exports of American matsutake to Japan from North America initiated in the mid 1970s but have increased a thousand-fold since the mid 1980s. One of the key problems is the price variability in which the mushrooms traded in Japanese markets can have highly variable prices within a season or from one season to the next. This results in low wages paid to pickers and subsequent shortage of mushrooms due to lack of harvesters willing to pick at such low prices. The wild mushroom market is dictated by international commerce. Thus, the price paid to harvesters in each location can fluctuate from day to day in response to world markets, competition among buyers, and local and regional competition among harvesters.

In Saskatchewan, the industry began about 15 years ago and is concentrated mainly in Northern Saskatchewan with some harvesting in the Nipawin area. The wild mushroom industry has grown to a value of about $1M (Ivanochko, Pers. Comm.). The wild mushroom industry consists of harvesters; buyers; brokers; processors; exporters; which may include foreign importers, wholesalers, distributors, and retailers. The harvesters are usually Saskatchewan residents who are becoming increasingly concerned about the loss of good mushroom habitat.

The increased interest in wild mushrooms has increased the need for more information on wild mushrooms and their role in the forest ecosystem. Much of the mushroom research has been conducted on the West Coast where climatic and forest types are much different from the boreal forest. There is a strong need for the collection of baseline information on wild mushroom production in Northern Saskatchewan. This information could act as a basis for discussion and development of land use policies in Northern Saskatchewan and will be useful to mushroom harvesters, forest planners (government and industry), environmentalists and other interested parties. Information gained from this research could be used for developing harvest guidelines and recommendations. Due to unpredictable climates, the wild mushroom harvest can be extremely variable from year to year. Therefore, a minimum of three years research is required to initially collect sufficient data on wild mushroom production of two commercial species; chanterelles (*Cantharellus cibarius)* and pine mushrooms (*Tricholoma magnivelare*). Ecologic surveys will also determine suitable mushroom habitat and the climatic factors associated with production of these species in Sask. A multi-disciplinary team has been assembled to address: a) ecology, and b) economic aspects from c) an environmentally sustainable perspective. This project represents Stage I of this longer term initiative.

Goal:

To develop baseline data characterizing mushroom (*Cantharellus cibarius* and *Tricholoma magnivelare*) ecosites in Saskatchewan. This will include information on additional under and overstory plant and fungi species, mushroom pests and their control.

Objectives:

1) To identify and characterize ecosites of Chanterelle and Pine mushrooms.

2) To initiate mushroom survey and pest management experiments which help to ensure the sustainability of this resource.

3) To develop a knowledge database that can be used to develop land use policies that take into account wild mushroom habitat. This will include discussions with mushroom pickers and buyers to gain additional ground information on factors related to productivity and current harvesting practices and concerns.

2.0 Deliverables:

2.1 Mushroom site descriptors suitable for GIS query (e.g. stand type, stand age, stand density, geographical area, soil type, understory species, etc.) will be developed. As the program matures through Stages II and III, these mushroom site descriptors will become more refined and defined.

2.2 Develop estimates of Productivity/Economic value of both chanterelle and pine mushrooms to compare to other forest products.

2.3 Evaluate Remay (poly-spun fiber) field covers as a means to improve Pine mushroom quality (i.e. reduce insect infestation).

2.4 Provide an initial indication of important weather parameters that may influence productivity in a given year. These parameters would continue to be examined in greater depth in future studies.

2.5 Provide harvesting recommendations for chanterelles with respect to minimum harvest age in order to allow spore formation and release to occur.

3.0 Materials and Methods

3.1 Identify and Characterize Ecosites for Chanterelle and Pine Mushrooms

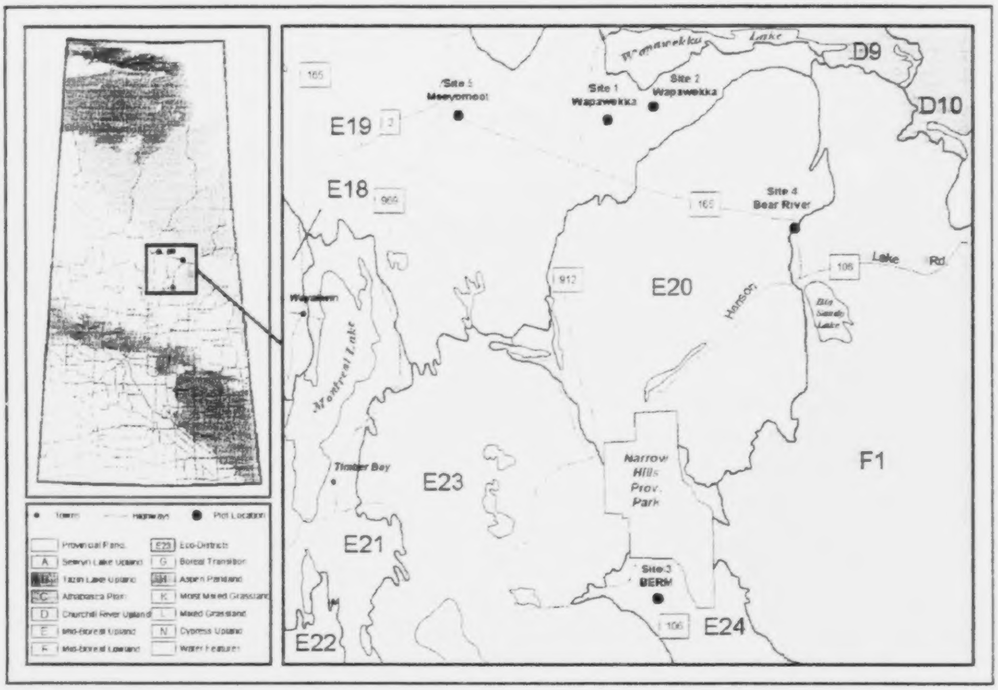
Three primary research sites were selected and are located at: GPS coordinates:

Site 1:	N 54° 47.903' W 104° 48.526' Weyerhaeuser logging camp (Wapawekka Lake)
Site 2:	N 54° 49.364' W 104° 39.763' Hills Road (Wapawekka Lake)
Site 3:	N 53° 54.985' W 104° 41.387' BERMS (OJP) (Narrow Hills)

These sites correspond to the Boreal Plain Ecozone and are in the Mid-boreal Upland Ecoregion. They are characterized by pure stands of jack pine at density B (moderately open canopy) and stand age of approximately 70-80 years. This characterization corresponds to an **a1 lichen jP** site classification (Canadian Forest Service, Northern Forestry Centre, 1996). The stand at Site #2 is listed as a SS20B JPBS 110 (softwood 20m high B density jack pine/black spruce stand that is 110 years old). Core sampling will be performed to confirm age.

The detailed sampling plots are located at mushroom research sites distributed across the eastern flank of the Mid-boreal Upland Ecoregion of central Saskatchewan (Figure 3.1). The Wapawekka and Meeyomoot research sites are located in the E19 Ecodistrict (La Ronge Lowland). The Bear River research site is located along the eastern flank of the E20 Ecodistrict (Wapawekka Upland). The BERM research site is located in the E24 Ecodistict (White Gull Plain).

Figure 3.1. Location of mushroom research sites.



Wapawekka Lake
D9
D10
165
Site 5 Meeyomoot
Site 1 Wapawekka
Site 2 Wapawekka
E19
2
E18
969
165
Site 4 Bear River
106
Lake Rd.
912
E20
Hanson
Big Sandy Lake
Montreal Lake
Weyakwin
Timber Bay
E23
Narrow Hills Prov. Park
F1
E21
Site 3 BERM
106
E24
E22
Towns
Highways
Plot Location
Provincial Parks
A Selwyn Lake Upland
B Tazin Lake Upland
C Athabasca Plain
D Churchill River Upland
E Mid-Boreal Upland
F Mid-Boreal Lowland
E23 Eco-Districts
G Boreal Transition
H Aspen Parkland
K Moist Mixed Grassland
L Mixed Grassland
N Cypress Upland
Water Features

3.1.1 Characterization/survey of these 3 sites

3.1.1.1 Vegetation characterization

This portion and part of the soil characterization were conducted by Jason Nelson and Ecodynamics Consulting International Inc. It included establishment of:

- a single 10 x 10 m ecosystem plot at each of the three existing mushroom research sites;
- 10 x 10 m ecosystem plots in the Bear River and Meeyomoot mushroom harvesting areas (one in each); and
- specific site, soil, forest and vegetation data at each plot to provide an ecological characterization of each mushroom site.

The project team decided to follow Saskatchewan Environment's (SE) Forest Ecosystem Classification (FEC) field sampling protocol to characterize the sites. The FEC program is focused on the ecological characterization of several thousand 10 x 10 m plots distributed across the forested Ecoregions of Saskatchewan. The plot data will be used to develop a new ecosite classification system and field guide for use in sustainable forest management and environmental assessment. Utilization of the FEC field sampling protocol in mushroom habitat assessment allows for future correlation of mushroom research results with the upcoming field guide and subsequent ecosite mapping. Ecosite classification and mapping is rapidly emerging as a primary tool for sustainable forest management, which considers all forest values, including non-timber forest products such as mushrooms.

As an interim measure, until a new ecosite guide is prepared, the sites were classified according to the existing Mid-Boreal ecosite guide (Beckingham *et al*., 1996).

Prior to establishing a 10m x 10m ecosystem plot at each site, the field team conducted a brief reconnaissance. In the case of the three previously established research sites (Sites 1 to 3), where flags indicate mushroom occurrence, the field team used these flags to estimate the approximate extent of the site. Once the extent was determined, the study team established a Tie-in Point (TIP) at the road-side, coincident with the centrepoint of the longest axis of the research site. A preset distance between 25 and 100m (in 25m increments) was chosen such that the plot would be located within the approximate centre of the research site, while minimizing bias. This approach was designed to be consistent with the ecological sampling method advocated by Mueller-Dumbois and Ellenburg (1974) – 'subjective without pre-conceived bias'.

In the case of the Bear River and Meeyomoot sites, which had not yet been established, the field team focused on establishing the plots in relatively undisturbed, healthy, mature (>40 years old) forest that had evidence of past mushroom harvesting. Again the team established a Tie-in Point at roadside and used a preset distance and interval (25m) to minimize bias. Both the Tie-in Point (TIP) and the four corners of the plot were permanently marked with aluminum posts, spray-painted blue and orange, as per the FEC protocol.

Heights and dbh (diameter, breast height) was measured for all trees within the plot >7.5 cm dbh, including dead trees. A prism sweep (BAF 2) was conducted at plot centre for forest volume assessment. Stand structure, crown closure, and species composition was also described. Two representative codominant trees of each species were selected outside of the plot for aging. Species composition and abundance (% cover) was assessed for each overstorey and understorey vegetation layer in 2m x 2m vegetation subplots located in the NW and SE corners of the main plot. The presence and abundance of any understorey species present in the main plot, but not recorded in the subplots, was also recorded. Abundance of all trees and shrubs >2m were also re-recorded for the main plot.

Once the plot description was completed, lichens and bryophytes (both arboreal and ground) were collected in the main plot for diversity analysis. On the way out, each TIP was marked with a metal tag indicating the plot name, the UTM coordinates, and date.

3.1.1.2 Soil Characterization

A soil pit was excavated to approximately 1m at a representative location outside of the plot for soil description and classification. The soil profile characterization included: descriptions of all major soil horizons (horizon type, thickness, texture, mottling, gleying, calcareousness, and coarse fragment content); parent material classification; humus form; seepage; drainage class; moisture and nutrient regimes; and depths to mottling, gleying, water table and root-restricting layer. Site characteristics, including topographic position, aspect, and slope angle, were also collected. The GPS coordinates of the plot centre were recorded using a Trimble GeoExplorer 3 (2-5 metre post-processed accuracy). A representative photograph was also taken at each site.

Field sampling procedure is pictured in Fig. 3.2 and was conducted on September 17, 2001. One hole was dug and several sub-samples were taken. The following data were taken:

- Soil macro- and micro-nutrients including total organic matter and carbon at various strata to a depth of 10 cm.
- Soil type
- Soil texture
- Groundcover species including other fungi at a radius of 2 m. around the patch.
- Soil moisture at 5 cm depth on juvenile and mature sporocarps
- Distance from the middle of the patch to the nearest tree.
- An attempt will be made to measure total yield of chanterelle and pine mushrooms from secure sites. Total yield will be calculated according to mushroom number (pine and chanterelle), cap size, and stem diameter

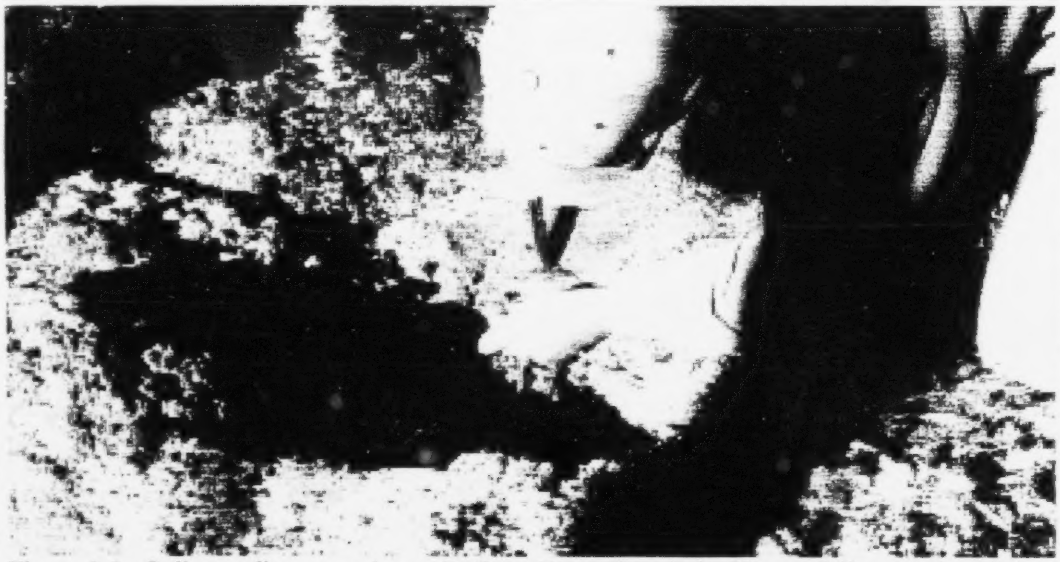


Figure 3.2. Soil sampling procedure: (1) dig a 60-cm deep hole; (2) carefully sample soil from each horizon, place in labeled bag for analysis; and (3) sample soil both within an identified mushroom patch and 10 m away from the nearest patch. Sampling was performed at each mushroom study site on September 17 2001.

(chanterelle) at each patch.

The 2001 soil samples were also further analyzed. The experimental unit was defined as a "patch" with separate patches located a minimum of 10 m apart. Elevation and ground cover were characterized. The following were sampled at both: a) within mushroom patches ("IN") and b) sites nearby without mushroom populations ("OUT") that are outside of the 10 m patch or tree root zone. These "IN" and "OUT" sites referred to chanterelle patches. One hole was dug and several sub-samples were taken. In 2002, the following data was additionally taken:

- Soil pH
- TDS
- K$^+$
- NO $^{3-}$

This data was taken at 2 soil depths: 0 to 2-5 cm; and 2-5 cm to 10 cm depth. The latter represents the level of the Active Mycorrhizal Zone (AMZ) from which fruiting bodies emerge.

Slope position will also be considered when sampling, resulting in multiple samples along a slope gradient.

Marc St. Arnaud, Sask. Land Resource Center, conducted field sampling
Barry Goetz, Sask. Land Resource Center, conducted laboratory analysis

Terms and Definitions:

h – hummocky
u – undulating
The number in front of the 'surface expression' denotes slope class:

Slope class	Percent slope	Approx. degress	Terminology
1	0-0.5	0	level
2	0.5-2.5	0.3-1.5	nearly level
3	2-5	1-3	very gentle slopes
4	6-9	3.5-5	gentle slopes

Mineral Horizons: contains ≤ 17% organic C by weight (= approx 30% organic matter)

A -This is a mineral horizon formed at or near the surface in the zone of leaching or eluviation of materials in solution or suspension, or of maximum in situ accumulation of organic matter or both. The accumulation of organic matter is usually expressed morphologically by a darkening of the surface soil (Ah), and conversely the removal of organic matter is usually expressed by a lightening of the soil color usually in the upper part of the solum (Ae). The removal of clay from the upper part of the solum (Ae) is expressed by a coarser soil texture relative to the underlying subsoil layers. The removal of iron is indicated usually by a paler or less red soil color in the upper part of the solum (Ae) relative to the lower part of the subsoil.

B -This is a mineral horizon characterized by enrichment in organic matter, sesquioxides, or clay; or by the development of soil structure; or by a change of color denoting hydrolysis, reduction, or oxidation. The accumulation in B horizons of organic matter (Bh) is evidenced usually by dark colors relative to the C horizon. Clay accumulation is indicated by finer soil textures and by clay cutans coating peds and lining pores (Bt). Soil structure developed in B horizons includes prismatic or columnar units with coatings or stainings and significant amounts of exchangeable sodium (Bn) and other changes of structure (Bm) from that of the parent material. Color changes include relatively uniform browning due 10 oxidation of iron (Bm), and mottling and gleying of structurally altered material associated with periodic reduction (Bg).

C -This is a mineral horizon comparatively unaffected by the pedogenic processes operative in A and B, (C), except the process of gleying (Cg), and the accumulation of calcium and magnesium carbonates (Cca) and more soluble salts (Cs, Csa). Marl, diatomaceous earth, and rock no harder than 3 on Mobs' scale are considered to be C horizons.

Relevant lower case descriptors:

e - A horizon characterized by the eluviation of clay, Fe, Al, or organic matter alone or in combination. When dry, it is usually higher in color value by one or more units than an underlying B horizon. It is used with A (Ae).

h - A horizon enriched with organic matter. It is used with A alone (Ah), or with A and e (Ahe), or with B alone (Bh), or with B and f (Bhf).

  Ah -A horizon enriched ~:th organic matter, it has a color value at least one unit lower than the underlying horizon or O.5~. more organic C than the IC or both. It contains less than 17% organic C by weight.

  Ahe -An Ah horizon that has undergone eluviation as evidenced, under natural conditions, by streaks and splotches of different shades or gray and often by platy structure. It may be overlain by a dark-colored Ah and underlain by a light-colored Ae.

  Bh -This horizon contains more than 1% organic C, less than 0.3% pyrophosphate-extractable Fe, and has a ratio of organic C to pyrophosphate-extractable Fe of 20 or more. Generally the color value and chroma are less than 3 when moist.

m - A horizon slightly altered by hydrolysis, oxidation, or solution, or all three to give a change in color or structure, or both. It has:

1. Evidence of alteration in one of the following forms:
    a. Higher chromas and redder hues than the underlying horizons.

b. Removal or carbonates either partially (Bmk) or completely (Bm).
c. A change in structure from that of the original material.

2. Illuviation, if evident, too slight to meet the requirements of a Bt or a podzolic B.
3. Some weatherable minerals.
4. No cementation or induration and lacks a brittle consistence when moist.

This suffix can be used as Bm, Bmgj, Bmk, and Bms.

Brunisolic Soils (Figure 3.3)

Soils of the Brunisolic order have sufficient development to exclude them from the Regosolic order, but they lack the degree or kind of horizon development specified for soils of other orders. The central concept of the order is that of soils under forest having brownish-colored Bm horizons, but the order also includes soils of various colors with both Ae horizons and weakly expressed B horizons of accumulation of either clay (Btj), or amorphous Al and Fe compounds (Bfj), or both. Soils having a Bf horizon less than 10 cm thick are a part of this order.

A Bm horizon may have any or all of the following: stronger chroma and redder hue than the underlying material, partial or complete removal of carbonates, slight illuviation based mainly on the occurrence of an overlying Ae horizon, a change in structure from that of the original material. They may develop in materials of any color, such as gray, brown, black or red, which vary in texture from gravel to clay.

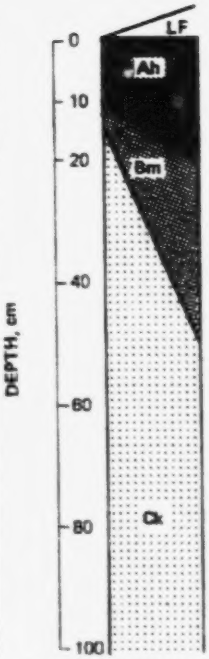


Figure 3.3. Typical (generic) Orthic Brunisol soil of the type that we are dealing with. See description of Brunisol above for deviations (e.g. Ae instead of Ah).

NOTE: L and F at top of the profile indicate possible organic layers: L = organic horizon mainly composed of easily recognizable leaves, twigs and woody material; or F = organic horizon composed of partially decomposed leaves, twigs and woody materials, somewhat difficult to identify.

Fluvial Deposit

Fluvial: Sediment generally consisting of gravel and sand with a minor fraction of silt and rarely clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well sorted and display stratification, but massive, nonsorted fluvial gravels do occur. These materials have been transported and deposited by streams and rivers.

The assumed process status is inactive.

Examples: channel deposits, overbank deposits, terraces, alluvial fans, and deltas.

The information from 'Terms and Definitions' to this point was taken directly from: Agriculture Canada Expert Committee on Soil Survey. 1987. Canadian System of Soil Classification. 2nd ed. Agric. Can. Publ. 1646. 164 pp.

Additional locations (100 m^2) of known high mushroom production were characterized according to:

- Tree species
- Age of tree(s) closest to patch
- Tree density
- Ground cover vegetation
- Depth of lichen and debris cover.

3.1.1.3 Weather data and correlations with mushroom yield:

Weather stations were again established at Sites 1, 2 and 3 (Fig. 3.4). Mushrooms were located within 10 m of the weather station. The following environmental data were taken hourly at each of the 3 sites from May 15, 2002 until the beginning of October:

- Soil temperature at 5 cm depth
- Air temperature (Maximum/minimum) at 30 cm height
- Soil moisture at 5 cm depth
- Relative Humidity at 30 cm above ground level

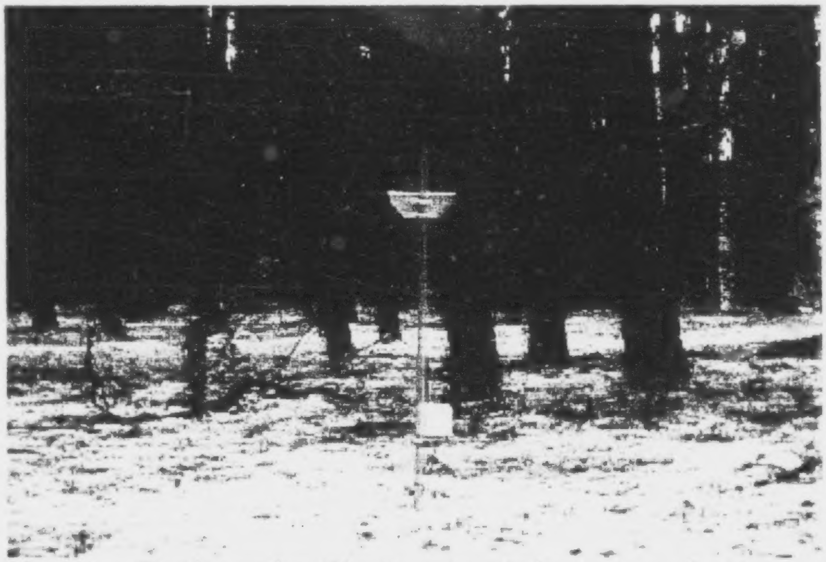


Figure 3.4. Weather station (Site 1): green rain bucket (top of pole), air temperature (°C) & relative humidity (%) (white sensor protector, 25 cm from lichen layer on pole), and soil temperature (°C) & soil moisture (kPa) (black cables attached to sensors 5 cm below soil surface)

Weather parameters correlated with mushroom yield response

In addition from 2002-2004, daily purchase volumes for Chanterelle and Pine mushrooms revealed the most productive areas were around research sites #1 and #2 and the Meeyamoot area for chanterelles and the Johnson River area (250 km north of La Ronge) for pine mushrooms.

Since weather stations on Sites 1, 2 and 3 were located in the chanterelle harvest region and not the pine mushroom region (this area was located much further north), correlations based on daily and cumulative data were performed between the meteorological data and presence of chanterelle mushrooms. The meteorological data was first averaged between the 3 sites in order to obtain a broad weather response over the region from which chanterelle mushrooms were harvested. While mushrooms were also collected on the weather station sites, competition with harvesters precluded accurate yield information. Specifically tests were run to determine:

a) If there is an optimum GDD base air temperature; timing of important weather parameters prior to yield response; if correlations of air or soil temperature, rainfall, soil moisture or humidity are correlated with timing and volume of chanterelle yield in 2002, 2003 and 2004. Correlations were performed between daily yield and: air temperature growing degree days (GDD) at varying base temperatures (0, 2, 5, 7, 10, 12, 15°C); humidity, rainfall, and soil moisture for the following time periods: 0 shift (i.e. correlations run when yield and meteorological data coincide according to calendar date), 2 day shift (correlations run when meteorological data are shifted by 2 days prior to the calendar date initiation of chanterelle purchase volumes), 4, 6, 8, 14, 18, 21, 28 day, 6 week, 8 week, 10 week and 12 week shifts in each of 2002, 2003 and 2004 years. Multiple regression analysis was also performed between these parameters and daily yield.

b) The average and cumulative GDD air and soil temperatures at and during the critical time period prior to the initiation of chanterelle purchase volumes.

c) Minimum, maximum and average temperatures for the period during and at the end of harvest in 2002, 2003 and 2004.

3.1.1.4 Yield Estimations

Total yield of chanterelle mushrooms from secure sites at Nipekamew River (Fig. 3.5) and Bow River (Fig. 3.6) areas were measured in 2002, 2003 and 2004. Total yield was calculated according to total weight within each stand. Yield data was only collected from Bow River site in 2002.

The investigators went to great lengths to locate isolated areas away from pickers. Several additional pieces of equipment were required to conduct this trial including ATV's, a canoe and a trailer (Figs. 3.7, 3.8, 3.9).

The yield estimates and stand surveys (section 4.1.2) were conducted in conjunction with Cliff Jessup of Watabeag Consultants. Prince Albert. SK.

Strip Yield data was compared to harvesting total yield from the entire stand.

a) Total Yield from the entire stand

On August 26, 2002, 11.3 ha of the Bow River remote site was harvested with a total harvest of 12.8 kg. This resulted in a yield of 1.13 kg/ha.

b) Strip Yield.

By contrast, a strip yield plot in the same region on August 29, 2002 on a strip 2 m wide by 860 m in length (0.17 ha) and resulted in a harvest of 0.48 kg of chanterelles. Harvest yield from this site was then 2.82 kg/ha.

Since in this case, the strip yield value of 2.82 kg/ha would have overestimated the actual yield based on 11.3 ha, it was decided to take yield data based on harvesting the whole stand rather than relying on a strip yield estimate.

Fig. 3.5 Nipekamew site. Portion within red indicates harvested area

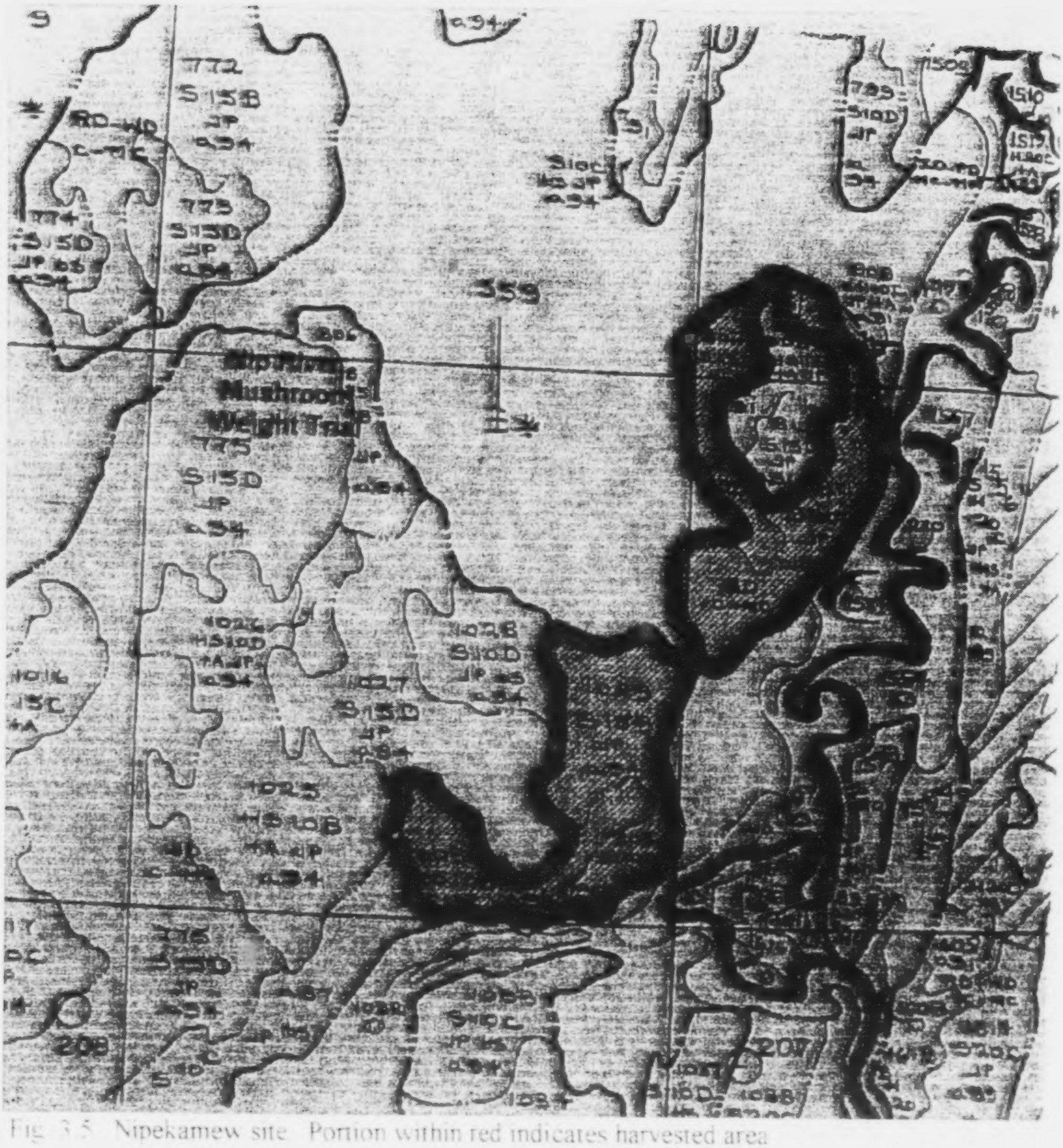

772
S15B
JP
359
Mushroom
Weight Trial
775
S15D
1028
S10D
1027
1025
208
207

Fig. 3.5 Nipekamew site. Portion within red indicates harvested area

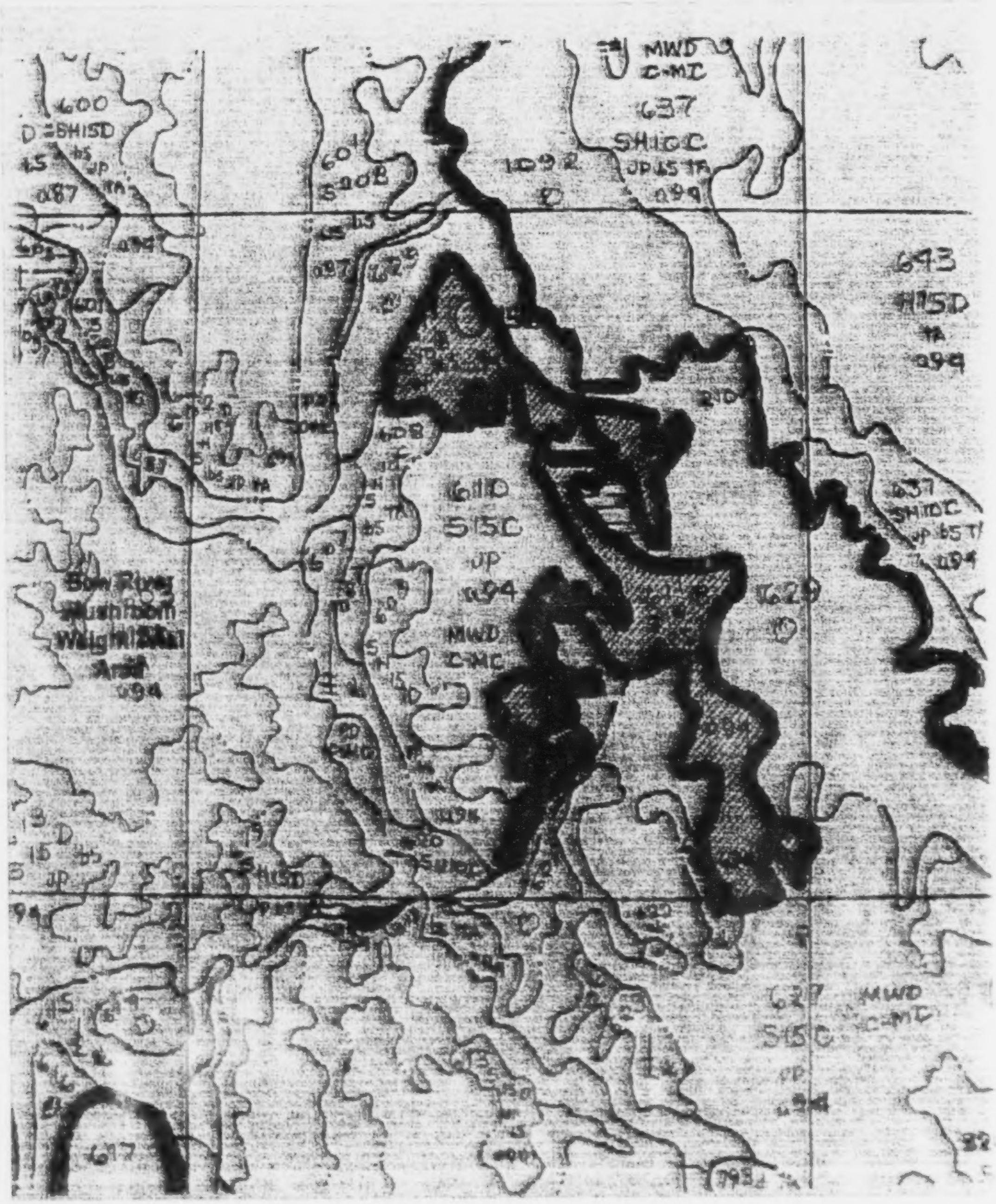

MWD
C-MC
637
SH10C
JP
099
600
D=BH15D
087
604
1092
D
643
H15D
TA
099
610
515C
JP
094
MWD
C-MC
629
D
637
SH10C
094
Bow River
Mushroom
Weight
Area
094
627
MWD
C-MC
515C
JP
094
617

Fig. 3.6 Bow River Site. Portion within red indicates harvested area

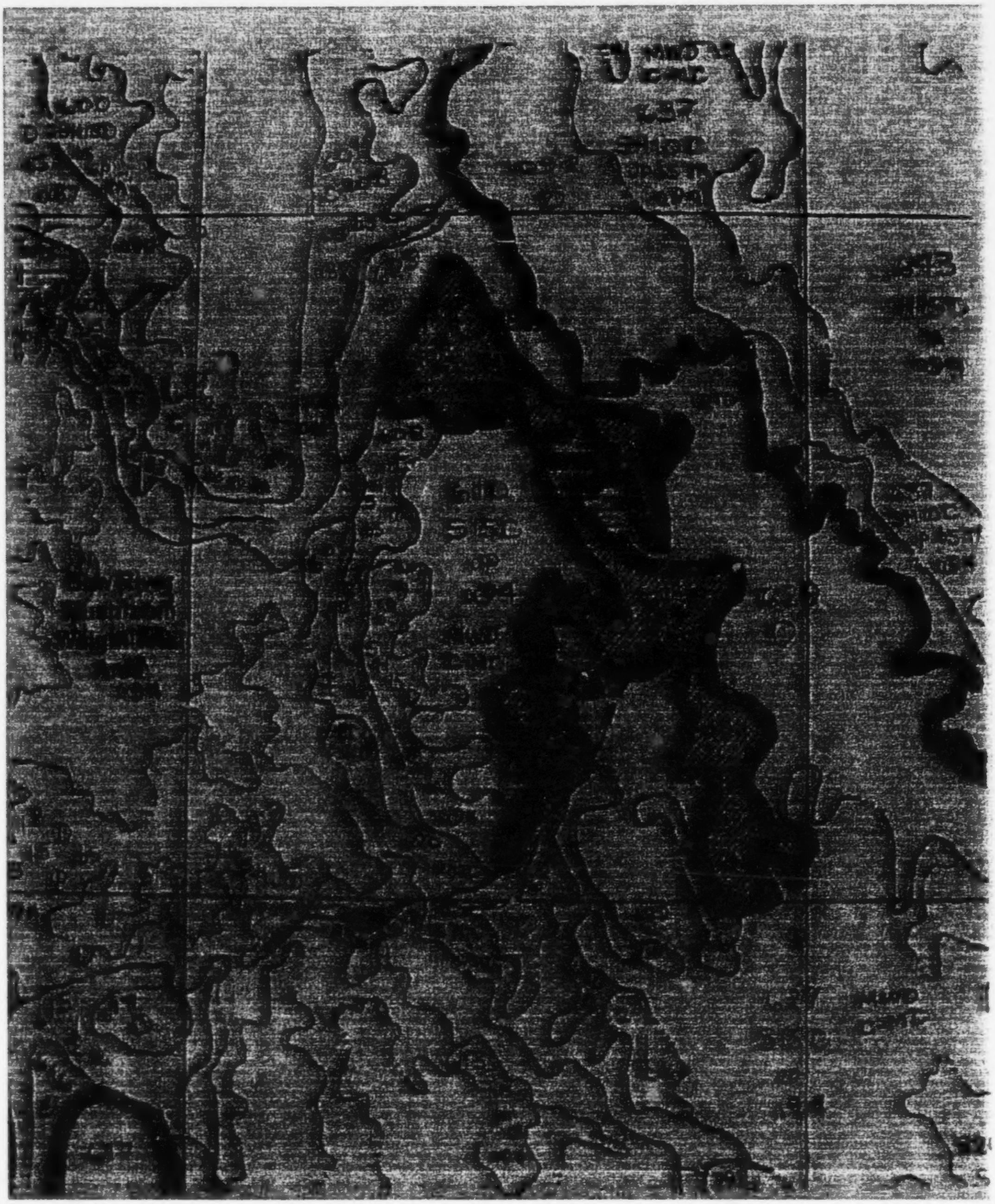


Fig. 3.6 Bow River Site. Portion within red indicates harvested area.

Fig. 3.7 Cliff Jessup and assistant with equipment (Gerry Ivanochko photographer)

Fig. 3.8 Cliff Jessup, assistant enroute to yield site (Gerry Ivanochko photographer)

Fig. 3.9. Remote yield location.

3.1.2 Survey of chanterelle and pine mushrooms

Objective: to survey presence/absence of chanterelle and pine mushrooms as a function of tree host species (jack pine versus jack pine/black spruce), stand age and density (crown closure), keeping ecoregion constant.

A total of 106 and 83 sites were surveyed in 2002 and 2003, respectively. Due to lack of sites in some classes, there was uneven representation for some classes. Nevertheless, in general four stand ages (<20 years, 20-40 years, 40-60 years, and >60 years), 2 densities (A/B and C/D) and 2 species (Jack Pine, Jack Pine/Black Spruce) were surveyed. A reconnaissance survey was conducted through a presence or absence of chanterelle and pine mushrooms recorded on a per stand area. A survey was conducted using a transect through the center of each stand. Once mushrooms were observed within a stand, that stand was recorded as "present" and no further sampling was conducted within that particular stand. If mushrooms were not observed on the first line transect through the center of the stand, then observations were taken on the second line back to the originating point.

Sampling procedure were conducted as follows:

- Stands were selected according to the Weyerhaeuser and SERM maps.
- Stands for transects were identified through GPS coordinates and SERM descriptions.

3.2 Sustainability

3.2.1 Sporulation

Objective: to determine the chanterelle developmental stage when spore formation and release occurs. This will lead to guidelines/recommendations for harvest of chanterelle mushrooms after spore release based on a morphological characteristic(s).

Before performing this test, recognized experts on this topic were e-mailed and their responses are included in this report.

3.2.2 Identification of pest species

Objective: Identify Pine mushroom insect pest species, determine life cycle and best method of control.

- Patches of pine mushrooms had been identified and marked in 2001. Those 4 sites (designated "A, B, C and D") were covered with Remay field covers (spun-bonded polypropylene). Field covers were of sufficient size to completely cover the patch.
- Pine mushrooms under the Remay cover were sampled, sliced open for visual observation and incubated for insect counts. Only sites "A" and "D" contained pine mushroom growth.

- Adults were raised in insect rearing cages from fresh mushrooms. Cages were incubated at 24C for 3 weeks and adults were collected over this time.
- Adults were sent to Scott Hartley (Sask. Ag. & Food) for identification. He subsequently sent the flies to Peter Mason (Agriculture and Agrifood Canada) for final identification.

Year 1:

- Identify and mark pine mushroom patches for application of Remay field covers (spun-bonded polypropylene) in Year 2. Field covers will be of sufficient size to completely cover the patch.
- Hatch larvae, mount adults and send to Biology Dept. (Dr. Randell) and Ottawa (AAFC) for identification. Once identified, gather information on its life cycle and habits over the winter.

Year 2:

- Apply field covers to 5 shiros (= patches) in an appropriate time of the year according to the life cycle of the insect as determined in Year 1.
- Monitor mushrooms for presence of larvae in stems both under and outside of field covers.

3.3 Development of Knowledge Base

Consultation with buyers and pickers.

Buyers: were consulted to obtain an estimate of yield, quality of Chanterelle and Pine mushrooms for a certain time period in that region. It is recognized that mushrooms may be coming from different regions such that this latter data may not be accurate. Nevertheless, over several years, a pattern may emerge. In addition, yield and quality can be analyzed according to weather for any given year and ecoregion.

Pickers: Pickers were consulted about sites where they harvest to identify locations for the inventory.

4.0 Results and Discussion

4.1 Identify and Characterize Ecosites for Chanterelle and Pine Mushrooms

4.1.1 Vegetation Characterization

Gerry Ivanochko, Erl Svendsen and Karen Tanino met with Kerry McIntyre and Dave Lindenas of Weyerhauser on May 2, 2001. They supplied maps based on stand age, species and density.

The upland forests of this Ecoregion are typically mixed-wood, with various combinations of coniferous (white spruce, black spruce, jack pine, balsam fir) and

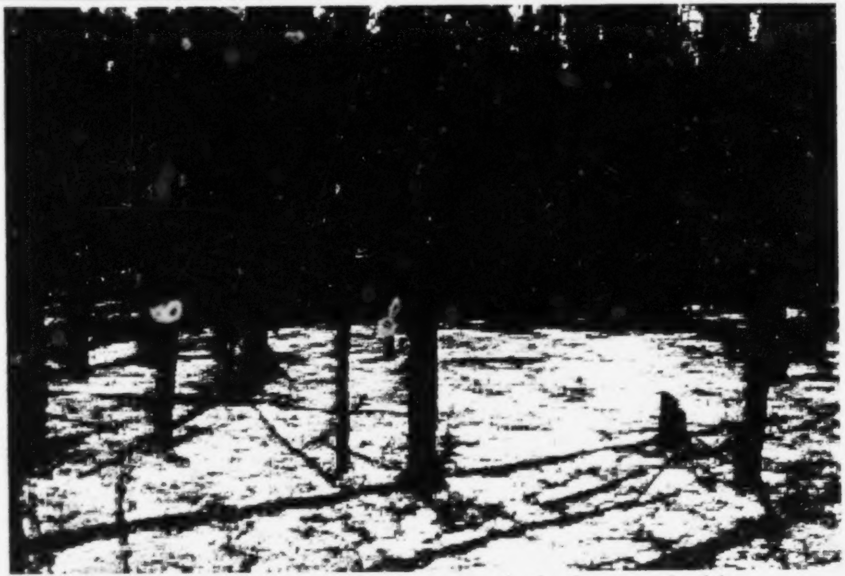


Figure 4.1. Typical mushroom habitat: open jack pine stand with predominately lichen ground cover.

deciduous (trembling aspen, balsam poplar and birch) tree species. Deciduous and mixed conifer-deciduous forests are characteristically rich is understorey shrubs and herbs, while coniferous forests tend to encourage a moss- and lichen-rich understorey.

A typical mushroom habitat in Sites 1, 2 or 3 is an open jack pine stand (density C/D) with predominantly lichen ground cover (Fig. 4.1).

Age of selected stands were determined through tree core sampling (Fig. 4.2).

- Site 1: 95 – 105 years

- Site 2 has two age groups.
    - 55 years
    - 100 – 115 years

- Site 3: 75 – 80 years
- Site 4 (Remay site) (N 54° 39.119', W 105° 31.446')
- young stand with average age of 55 years.

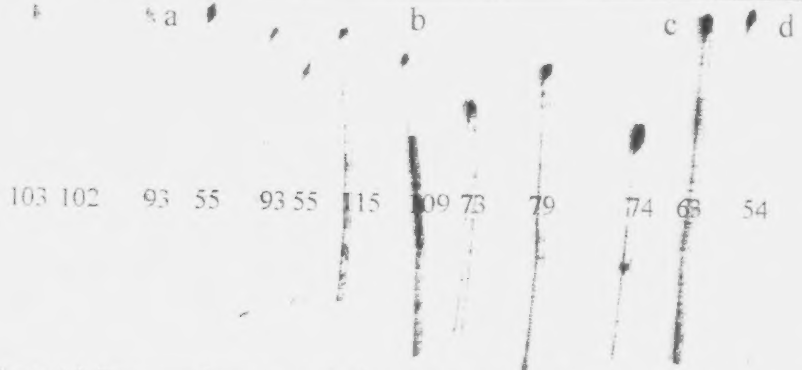


Figure 4.2. Tree cores from trees at the four mushroom study sites. The number overlaying each core is an indication of the tree's age. (a) Site 1 average age is 95 – 105; (b) Site 2 has trees of two ages, 55 years and 100 - 115 years; (c) Site 3 average age is 75 – 80; and (d) Site 4 (Remay site) is a young stand with an average age of 55

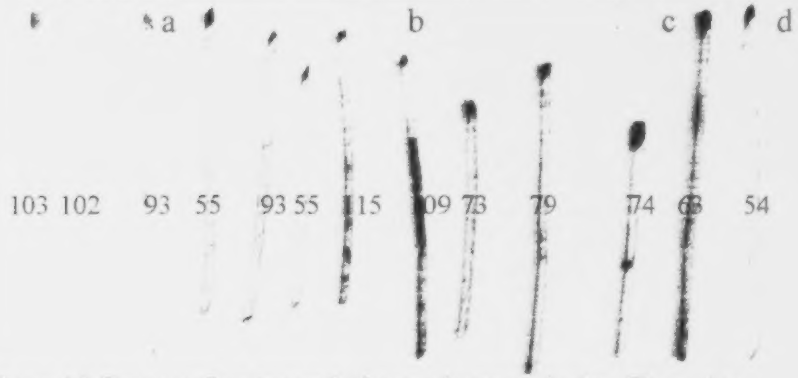
Trees and Shrubs. Jack pine (*Pinus banksiana*) was the only tree species recorded, and was present in all tree & shrub layers, with most of the total cover found in the dominant and co-dominant layers (Table 4.1). The mean cover of jack pine in all layers >2m was 29.4%, which lies on the boundary between the A and B stand density classes used in past Saskatchewan forest inventories.

The observed tree densities at the plots were consistently lower than the forest inventory polygon descriptor (Table 4.2). This is a phenomenon often observed when establishing only one plot within a stand, since one relatively small plot cannot capture the stand density and height variations within the polygon. Also, due to scale limitations, there are always "inclusions" of other types too small for the inventory forester to map.

Shrubs were only present in the <0.5m layer. The most prominent shrubs in terms of frequency and mean cover were *Vaccinium angustifolium* (blueberry) and *Arctostaphylos uva-ursi* (bearberry), each with a mean covers >2% and a frequencies of 80%.

In the Pacific Northwest region of the United States, the matsutake mushroom is typically found under a thick layer of moss or leaf litter, vine maple (*Acer circinatum*), and a variety of ericaceous shrubs (Jong, 2004). Candystick plants (*Allotropa virgata*), which parasitize the fungus, are consistently observed near all host trees wherever matsutake grows in both the Pacific Northwest and in British Columbia. Candystick propagates through rhizomatous growth and provide pickers with a visual indicator of matsutake in that region. While *Allotropa* plants or ecotypes were not observed in our study, the ericaceous shrubs of *Vaccinium* and *Arctostaphylos* were found.

In British Columbia, matsutake has been found in well-drained, nutrient-poor sites on coarse-textured soil. This mushroom has been associated with the Interior Cedar



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Hemlock, Sub-Boreal Pine-Spruce, Engelmann Spruce-Subalpine fir, Interior Douglas fir, and Coastal Western Hemlock biogeoclimatic zones.

Forbs and Graminoids. Forbs and graminoids were both low in number of species and in their cover, which is consistent with dry jack pine stands. There were only two notable species within the forbs and graminoid layer with frequency of occurrence greater than 60% - *Oryzopsis pungens* (northern rice grass) and *Maianthemum canadensis* (two-leaved Solomon's seal or wild-lily-of-the-valley). The low cover of *M. canadensis* may be attributed to the lateness of the season.

Lichens and Bryophytes. During species cover estimation in the field, some moss and lichen species were grouped at the genus level due to difficulties in field identification (Table 4.2). However, lichen and bryophyte specimens within these genera were collected and later identified in a laboratory setting. Appendix B presents the results of this species identification work, along with their frequency of occurrence.

It appears that the most important among the bryophyte and lichen species recorded, in terms of both frequency of occurrence and mean cover, were the "reindeer lichens" – *Cladina mitis*, *Cladina stellaris*, and *Cladina rangiferina*. Combined, this lichen group covers nearly 60% of the bryophyte and lichen layer.

Also of note were the *Cladonia* genus of lichens, which were grouped during cover estimation. While relatively low in cover (<1% mean cover) this lichen group showed a relatively high degree of species richness (17 species) and occurrence (100% frequency). Most were 'pixie-cup lichens', the only exception was *C. uncialis* (Prickle cladonia or spike lichen), which had both a relatively high frequency (80%) and mean cover (1.6%). The "leaf lichens" (*Peltigera spp.*), which were also grouped during cover estimation, also exhibited a notable frequency of occurrence (80%) and mean cover (1.6%).

While at only three of the five plots (60%), *Pleurozium schreberi* (Shreber's moss), was the most conspicuous moss among the sites (mean cover of 2.7%). Moss species within the *Polytrichum* and *Dicranum* genera, were also notable, with frequencies of occurrence of 100% and 80%, respectively.

Ecological Classification. Using the *Field Guide to Ecosites of the Mid-Boreal Ecoregions of Saskatchewan* (Beckingham et al., 1996), all the plots fall within the *a1 - lichen jP Ecosite Phase*. At the level of *Plant Community Type*, three of the five are classified as the *a1.1 jP/bearberry/lichen* community. One remained unclassified at this level and one was classified as a *jP/blueberry/lichen* plant community type. Based on vegetation mean cover and frequency data (Table 4.2), the 'modal' or typical Plant Community Type appears to be the *a1.1 jP/bearberry/lichen* community.

Table 4.1. Summary of detailed plot data.

SITE	Site 1 (Wapawekka)	Site 2 (Wapawekka)	Site 3 (BERM)	Site 4 (Bear River)	Site 5 (Meeyomoot)
Ecological Classification					
Ecoregion	Mid-boreal Upland	Mid-boreal Upland	Mid-boreal Upland	Mid-boreal Upland	Mid-boreal Upland
Ecodistrict	E19 - La Ronge Lowland	E19 - La Ronge Lowland	E24 - White Gull Plain	E20 - Wapawekka Upland	E19 - La Ronge Lowland
Ecosite	a - lichen	a - lichen	a - lichen	a - lichen	a - lichen
Ecosite Phase	a1 lichen jp	a1 lichen jp	a1 lichen jp	a1 lichen jp	a1 lichen jp
Plant Community Type	a1.1 jP/blueberry/lichen	a1.1 jP/bearberry/lichen	- no fit -	a1.1 jP/bearberry/lichen	a1.1 jP/bearberry/lichen
Site Attributes					
Elevation (m)	422	436	516	411	420
Aspect (deg)	324	182	281	no aspect	no aspect
Slope (deg)	2-5	2-5	2-5	<0.5	<0.5
Slope Position	upper	mid-slope	lower-slope	level	level
Slope Shape	convex	convex	concave	level	level
Soil Attributes					
Soil Drainage Class	rapid - well	rapid	well - mod. well	rapid	rapid
Soil Moisture Regime	moderately fresh	moderately dry	fresh	moderately dry	moderately dry
Ecological Moisture Regime	subxeric - submesic	subxeric	submesic	subxeric	subxeric
Nutrient Regime	poor	poor	poor	poor	poor
Surface Texture (0-30 cm)	medium sand	fine sand	fine sand	medium sand	fine sand
Effective Texture	fine sand	fine sand	fine sand	fine sand	fine sand
Coarse Fragments (0-30 cm)	<1%	0%	0%	0%	0%
Organic (Duff) Thickness (cm)	2	2	3	2	3
Soil Classification					
Parent Material	glaciofluvial	fluvial-lacustrine	fluvial-lacustrine	glaciofluvial	fluvial-lacustrine
Soil Subgroup	Eluviated Eutric Brunisol	Eluviated Eutric Brunisol	Eluviated Eutric Brunisol	Eluviated Eutric Brunisol	Eluviated Eutric Brunisol
Humus Form	Fibrimor	Fibrimor	Fibrimor	Fibrimor	Fibrimor
Stand Characteristics					
Forest Inventory Stand Type	S15C jP	S20B jPbS	S15D jP	S10B jPbS	S10D jP
Stand Density within Plot*	B (B-C)	A (A-C)	B (B-C)	A (A-B)	A (A-B)
Average Tree Height (m)**	13.3 (6.9 - 17.2)	15.4 (13.5 - 16.8)	11.4 (7.9 - 14.0)	11.6 (10.0 - 13.9)	9.6 (8.0 - 11.3)
Average DBH (cm)**	14.5 (7.7 - 20.6)	18.6 (13.8 - 23.4)	11.7 (7.6 - 18.0)	15.5 (11.1 - 21.1)	9.7 (7.5 - 13.4)
Stand Age (years)	88	77	75	52	51
Basal Area (m2)	16	11	7	5	5
Net Volume (m3)	142.2	112.1	53.4	38.8	31.9

* Density variation of surrounding stand in brackets

** Range in brackets

Table 4.2. Vegetation cover data.

		Site 1 (Wapawekka)				Site 2 (Wapawekka)				Site 3 (BERM)				Site 4 (Bear River)				Site 5 (Meeyomoot)				Averages	
SPECIES BY LAYER	**Layer Code**	**NW**	**SE**	**Main**	**Plot Ave.**	**NW**	**SE**	**Main**	**Plot Ave.**	**NW**	**SE**	**Main**	**Plot Ave.**	**NW**	**SE**	**Main**	**Plot Ave.**	**NW**	**SE**	**Main**	**Plot Ave.**	**% F**	**% MC**
Dom. Tree Layer (>10m)	**1**																						
PINUBAN				10.0	10.0	10.0	20.0	20.0	20.0	62.5	3.0	37.5	37.5	10.0	20.0	10.0	10.0			10.0	10.0	■	17.5
Cod. Tree Layer (>10m)	**2**																						
PINUBAN		37.5	20.0	20.0	20.0			3.0	3.0			3.0	3.0			3.0	3.0					80.0	5.8
Trees & Shrubs (2-10m)	**3**																						
PINUBAN				0.5	0.5					0.5	3.0	10.0	10.0					10.0	3.0	20.0	20.0	60.0	6.1
Trees & Shrubs (0.5-2m)	**4**																						
PINUBAN				0.0	0.0							0.0	0.0			0.5	0.5					60.0	0.1
Trees & Shrubs (<0.5m)	**5**																						
PINUBAN				0.5	0.5			0.5	0.5					0.0			0.0			0.5	0.5	80.0	0.3
VACCANG		3.0	20.0		11.5			0.5	0.5			0.5	0.5	0.5			0.3					80.0	2.6
VACCVIT								0.5	0.5													20.0	0.1
ARCTUVA		3.0			1.5	10.0	3.0		6.5					0.5	3.0		1.8		0.5		0.3	80.0	2.0
POTETRI			0.5		0.3																	20.0	0.1
AMELALN														0.0			0.0					20.0	0.0
Forbs & Graminoids	**6**																						
ARALNUD								0.5	0.5	3.0	0.0		1.5									40.0	0.4
ANEMCAN												0.0	0.0									20.0	0.0
ANEMMUL										0.0			0.0			0.5	0.5					40.0	0.1
CAMPROT												0.0	0.0			0.0	0.0					40.0	0.0
HIERUMB												0.5	0.5			0.5	0.5					40.0	0.2
MAIACAN			3.0		1.5					0.5			0.3	0.0	0.0		0.0					60.0	0.4
MELAMLIN							0.5		0.3													20.0	0.1
SOLICAN												0.0	0.0		0.0		0.0					40.0	0.0
AGROSCA																				0.5	0.5	20.0	0.1
ORZOPUN				0.5	0.5			0.5	0.5		0.5		0.3			0.5	0.5					80.0	0.4
Brophytes & Lichens	**7**																						
CLADMIT		20.0	20.0		20.0	37.5	37.5		37.5	62.5	62.5		62.5	62.5	62.5		62.5	62.5	37.5		50.0	■	46.5
CLADSTE		20.0	10.0		15.0	3.0			1.5	3.0	10.0		6.5		0.5		0.3	10.0	10.0		10.0	■	6.7
CLADRAN		3.0	3.0		3.0	3.0			1.5	10.0	10.0		10.0	0.5	0.5		0.5	3.0	3.0		3.0	■	3.6
CLADUNC		0.5			0.3	3.0	3.0		3.0	3.0			1.5	3.0	3.0		3.0					80.0	1.6
CLADBOR				0.5	0.5			0.5	0.5					0.5			0.3					40.0	0.3
*CLADSPP		0.5			0.3	0.5	0.5		0.5	0.5	0.5		0.5	0.5	0.5		0.5	0.5	0.5		0.5	■	0.5
STERSPP				0.5	0.5									0.5	0.5		0.5					40.0	0.2
PELTSPP		3.0	0.5		1.8	0.5	3.0		1.8		3.0		1.5	3.0	3.0		3.0					80.0	1.6
PLEUSCH		3.0	10.0		6.5		3.0		1.5									0.5	10.0		5.3	60.0	2.7
PTILCRI			0.5		0.3		0.5		0.3													40.0	0.1
POLYSPP		0.5	0.5		0.5	0.5	0.5		0.5		0.5		0.3		0.5		0.3	0.5	0.5		0.5	■	0.4
DICRSPP		3.0	3.0		3.0		3.0		1.5	3.0	3.0		3.0					3.0	3.0		3.0	80.0	2.1

*CLADSPP Refers to various Cladonia species (pixie-cup lichens). %F Frequency of occurrence among plots. % MC Mean cover, all plots. 0.0 indicates cover of <1%, but only 1 plant

■ 100% frequency □ 80% frequency □ 60% frequency ▨ >=1% cover

In summary, the following ecological characteristics were most notable among the plots data:

- ***Consistency of Soil Profile and Parent Material Characteristics*** – All plots were underlain by Eluviated Eutric Brunisol soils, developed in stone-free, fine sandy deposits of fluvial-lacustrine or glaciofluvial origin with gentle topography;
- ***Consistency of Drainage Class, Moisture Regime and Nutrient Regime*** – Soils typically rapidly to well-drained, with subxeric to submesic ecological moisture regimes and poor nutrient regimes;
- ***Consistency of Overstorey and Understorey Species Composition*** – All plots had an overstorey entirely of jack pine; the understorey at most sites was dominated by reindeer lichens, bearberry and blueberry; and
- ***Consistency of Ecosite*** – All plots fall within the *lichen jP* ecosite phase, with 60% of plots supporting a *jP/bearberry/lichen* plant community type.

These results are consistent with past observations by mushroom harvesters and the regional agrologist in La Ronge. However, while a number of ecological parameters appear to be consistent across the five research areas, the reader is cautioned that this was not a comparative study; there were no comparisons with other ecosites in terms of pine and chanterelle mushroom occurrence (e.g., occurrence and productivity among different ecosite phases). Also, the question of whether or not these apparent consistencies will hold up with a larger sample size, remains an outstanding issue. A larger sample size is necessary before more categorical statements may be made about correlations between ecological variables and mushroom occurrence and productivity (e.g., identification of 'indicator species' among the vascular plants, bryophytes and lichens present in mushroom areas).

The question of consistency across ecosites is of particular importance, as today's ecologically-based inventories (e.g., Weyerhaeuser Forest Vegetation Inventory) will allow ecosite mapping in the near future. These maps will greatly assist in the identification of critical mushroom habitat over extensive areas, making the inclusion of mushroom habitat concerns into forest planning and management, that much easier.

One limitation of the existing ecosite guide is its relatively poor 'resolution' when ecologically classifying jack pine forests. The lichen jack pine ecosite phase (a1) does not capture enough of the ecological variability and subtleties within the jack pine growth type. Hopefully, the new ecosite guide being prepared by Saskatchewan Environment, will have more resolution in dealing with jack pine and jackpine-black spruce forests.

In the interim, the apparent correlation with forest cover, soil drainage, and soil texture, will allow some degree of predictive ability in identifying potential mushroom habitat, using existing soil and forest inventory maps.

4.1.2 Site and Soil Characteristics

The Mid-boreal Upland Ecoregion consists of a complex of rolling uplands and gently undulating plains, underlain by thick glacial drift, with only occasional exposures of Cretaceousaged bedrock. The hummocky uplands consist mainly of loamy, morainal (till) deposits, while the gently undulating plains are dominated by sandy glaciofluvial and glaciolacustrine materials. Various mixtures of Gray Luvisolic and Eutric Brunisolic soils predominate in areas underlain by glacial till. Areas underlain by sandy glaciofluvial and glaciolacustrine deposits usually exhibit Brunisolic soils, with occasional occurrences of poorly-developed Regosolic soils in areas reworked by winds (eolian deposits).

All of the sites were located in areas with level to gently undulating topography, with slopes < 5 degrees (<9%), and typically between 1 and 3 degrees (2 and 5%). Given the gentle topography, aspect was not a conspicuous characteristic. However, aspects were typically to the western side of the compass rose (three plots) or there was no aspect (two plots).

All of the plots were underlain by Eluviated Eutric Brunisol soils, developed in fluvial-lacustrine or glaciofluvial deposits. These observations were consistent with the provincial soil map, which indicated a predominance of soils belonging to the *Pine Association* in each research area (i.e., Eutric Brunisols developed in sandy glaciofluvial and glaciolacustrine deposits).

Soil textures were mostly fine sand, with minor occurrence of medium sand textures. Plot soils were typically rapidly to well-drained, with subxeric to submesic ecological moisture regimes. Nutrient regimes were consistently poor. Organic (duff) horizons were consistently thin (2-3 cm) Fibrimors.

Coarse fragments were conspicuously absent from most plot soils. Minor gravel fragments (<1%) were found only at one site (Site 1 – Wapawekka).The drainage and texture status of the soil profiles was consistent with drainage and textures indicated on both the provincial soil maps and forest inventory maps. This is consistent with other reports (e.g. Wiensczyk and Berch, 2001).

Soil Survey Report

Marc St. Arnaud, Sask. Land Resource Center, conducted field sampling
Barry Goetz, Sask. Land Resource Center, conducted laboratory Analysis

On September 17, 2001, soil samples were collected from 8 sites in and around the LaRonge area of Northern Saskatchewan. Soil samples were taken in areas of known mushroom production (IN) and in areas where mushrooms were not suspected of growing (OUT). Soil samples were taken from just below the surface organic "Duff" layer to a maximum depth of 10 cm. The soil samples were analyzed in January, 2002, for total Carbon, total nitrogen and total sulfur.

Site #1: (N 54° 47.903', W 104° 48.526')

Soils here are Orthic Brunisols developed on sandy gravelly Fluvial deposits.

Soil samples at this site were taken in both, areas of known mushroom growth (IN), and in an area of suspected no-growth (OUT).

Soil samples in the "IN" site were taken from the Ae (0 - 2 cm) and Bm (2 - 7 cm) horizons.
Soil samples in the "OUT" site were taken at same depths as with "IN" site

Site #2: (N 54° 49.364', W 104° 39.763')

Soils here are Orthic Brunisols developed on sandy Fluvial deposits. Topography at this site was 2 - 3 h.

Soil samples in the "IN" site were taken from an upper slope position on the landscape in the Ae (0 - 4 cm) and Bm (4 - 8 cm) horizons.

Two "OUT" sites were sampled at this location. The first was located in a wet mossy depressional area with samples taken in the Ae (0 - 5 cm) and Bm (5 - 10 cm) horizons. The second sampling site was at a lower slope position with samples taken in the Ae (0 - 2 cm) and Bm (2 - 7 cm) horizons

Site #3: (N 53° 54.985', W 104° 41.387')

Soils here are Orthic Brunisols developed on sandy Fluvial deposits. Topography at this site was 2 - 3 h.

Site #4 : Remay (N 54° 39.119', W 105° 31.446')

The Remay site is in a young 15 m Jack Pine stand.
Soils at this site are Orthic Brunisols developed on sandy, Fluvial deposits.
Topography of this site is gently undulating.
Soil samples at this site were taken in both, areas of known mushroom growth (IN), and in an area of suspected no-growth (OUT).

Additional sites:

Meeyamoot

The Meeyamoot site is in a young 10 m Jack Pine stand.
Soils at this site are Orthic Brunisols developed on sandy Fluvial deposits.
Topography of this site is gently undulating with some 3h hummocks in the area..
Soil samples at this site were taken in both, areas of known mushroom growth (IN), and in an area of suspected no-growth (OUT).

Soil samples in the "IN" site were taken from the Ae (0 - 1.5 cm) and Bm (1.5 - 5 cm) horizons.

The "IN" site was a dry site with lichens on the surface.
The "OUT" site was a wetter site with moss covering the surface. Soils sampled in the "OUT" site were taken at the same depths as with the "IN" site

Mackenzie Burn (N 54° 47.295', W 104° 47.955')

Stand age: 26 and 54 years.

This site is located in a 19-year-old burn. Soils here are Orthic Brunisols developed on sandy Fluvial deposits, on 3h topography.

Soil samples were only taken from an "IN" site at this location. Samples were taken from the Ae (0-2 cm) and Bm (2 - 8 cm) horizons.

Bear River (N 54° 34.137', W 104° 13.450')

Soils here are Orthic Brunisols developed on sandy Fluvial deposits, on 2u topography.

Soil samples were only taken from an "IN" site at this location. Samples were taken from the Ae (0-2 cm) and Bm (2 - 7 cm) horizons.

Ballantyne River (N 54° 29.919', W 103° 52.854')

Soils here are Orthic Brunisols developed on sandy Fluvial deposits.

Soil samples were only taken from an "IN" site at this location. Samples were taken from the Ae (0-3 cm) and Bm (3 - 8 cm) horizons.

Soil samples in the "IN" site were taken from the Ae (0 - 3 cm) and Bm (3 - 8 cm) horizons.

Soil samples in the "OUT" site were taken at same depths as with "IN" site.

The American matsutake and Japanese matsutake are similar both from a biological and ecological-based characteristic (Jong, 2004b). Matsutake produces a dense mycelial mass "shiro" (literally translated from Japanese as "white castle" or "fortress"). The surface of the shiro is immediately below the litter layer and in deep soil can be 25 cm thick.

Several zones are characterized in a soil profile of a shiro (Jong, 2004b). The currently active mycorrhizal zone (AMZ, zone III) contains the mycorrhizae directly below the mushroom (Figs. 4.3, 4.4). When fruiting occurs, the soil in the AMZ becomes strongly desiccated and the mycorrhizae begin to deteriorate. The AMZ contains about 10 times the number of fine rootlets compared to the adjacent zones. According to Wallander (1995), nitrogen deposits influence the growth of chanterelles but excess nitrogen may actually inhibit fruiting bodies. Optimum pH is 4.5-5.5 for chanterelle growth and pH should be analyzed in future studies.

As per Fig. 4.21, the AMZ zone in the matsutake mushrooms harvested in Saskatchewan appears to be about 5-7 cm below the soil surface. Accordingly, this zone and the surface layer were evaluated. Additional soil data based on samples (Marc St. Arnaud, Sask. Land Resource Center, conducted field sampling and Rensong Liu analyzed the soil samples) were analyzed both within (In) and outside (Out) of chanterelle mushroom patches (Table 4.4). Soil pH, NO^{3-}, K^{+}, and TDS were recorded. A simple t-test was run and compared values "IN" and "OUT" for each soil depth. These preliminary results showed no significant difference between the two sites at any of the soil depths tested (Table 4.5). However, greater sample size may reduce the variation.

"Zone II (Figs. 4.3, 4.4) contains young, physiologically active mycorrhizae that will produce mushrooms the following season. Although the matsutake mycorrhizae are classified as ectomycorrhizae, unlike most ectomycorrhizae they have loose, soft mantles with poorly developed Hartig nets. Zone I contains mycelia and structural roots but no mycorrhizae. Zones IV and V represent the previous two years of fruiting, in which soil is still granular and desiccated and contains decayed mycorrhizae. Finally, in zone 0 there is no mycelium, and zone VII shows complete recovery from the earlier effects of active mycorrhizae. All zones can be recognized in the field by variation in the color of the soil profiles, as well as soil texture, relative moisture, and odor (the unique matsutake aroma)" Jong (2004).

Table 4.3. Data from Soil Survey Laboratory for Marc St. Arnaud

Site	Depth (cm)	Total Carbon %	Total Sulfur %	Total Nitrogen %
Site # 4, REMAY_IN	0 - 5	1.780	0.0054	0.0492
Site # 4, REMAY_IN	5 - 10	0.534	0.0052	0.0169
Site # 4, REMAY_IN	10 - 15	0.235	0.0320	0.0125
Site # 4, REMAY_OUT	0 - 5	1.340	0.0022	0.0420
Site # 4, REMAY_OUT	5 - 10	0.586	0.0082	0.0194
Site # 4, REMAY_OUT	10 - 15	0.400	0.0041	0.0146
MEEYMOOT_IN	0 - 1.5	0.957	0.0084	0.0332
MEEYMOOT_IN	1.5 - 5	0.533	0.0118	0.0213
MEEYMOOT_OUT	0 - 1.5	0.575	0.0129	0.0210
MEEYMOOT_OUT	1.5 - 5	0.378	0.0018	0.0137
BEAR RIVER_IN	0 - 2	1.130	0.0075	[illegible]
BEAR RIVER_IN	2 - 7	0.579	0.0063	0.0200
MACKENZIE_IN	0 - 2	1.060	0.0180	0.0377
MACKENZIE_IN	2 - 7	0.576	0.0022	0.0197
Site #1_IN	0 - 2	2.840	0.0405	0.0904
Site #1_IN	2 - 7	0.445	0.0454	0.0219
Site #1_OUT	0 - 2	0.568	0.0011	0.0185
Site #1_OUT	2 - 7	0.277	0.0041	0.0114
Site #2_IN	0 - 4	0.654	0.0123	0.0102
Site #2_IN	4 - 8	0.370	0.0041	0.0129
Site #2_OUT	0 - 5	0.725	0.0145	0.0236
Site #2_OUT	5 - 10	0.272	0.0039	0.0170
Site #2, LOWER	0 - 2	0.866	0.0030	0.0247
Site #2, LOWER	2 - 7	0.206	0.0243	0.0096
Site #3_IN	0 - 3	1.190	0.0034	0.0364
Site #3_IN	3 - 8	0.505	0.0426	0.0222
Site #3_OUT	0 - 3	1.380	0.0080	0.0450
Site #3_OUT	3 - 8	0.524	0.0054	0.0197
BALLANTYNE_IN	0 - 3	1.010	0.0058	0.0328
BALLANTYNE_IN	3 - 8	0.429	0.0015	0.0191

Table 4.3 Data from Soil Survey Laboratory for Marc St. Arnaud

Site	Depth (cm)	Total Carbon %	Total Sulfur %	Total Nitrogen %
Site # 4, REMAY_IN	0 - 5	1.780	0.0054	0.0492
Site # 4, REMAY_IN	5 - 10	0.534	0.0052	0.0169
Site # 4, REMAY_IN	10 - 15	0.235	0.0320	0.0125
Site # 4, REMAY_OUT	0 - 5	1.340	0.0022	0.0420
Site # 4, REMAY_OUT	5 - 10	0.586	0.0082	0.0194
Site # 4, REMAY_OUT	10 - 15	0.400	0.0041	0.0146
MEEYMOOT_IN	0 - 1.5	0.957	0.0084	0.0332
MEEYMOOT_IN	1.5 - 5	0.533	0.0118	0.0213
MEEYMOOT_OUT	0 - 1.5	0.575	0.0129	0.0210
MEEYMOOT_OUT	1.5 - 5	0.378	0.0018	0.0137
BEAR RIVER_IN	0 - 2	1.130	0.0075	0.0308
BEAR RIVER_IN	2 - 7	0.579	0.0063	0.0200
MACKENZIE_IN	0 - 2	1.060	0.0180	0.0377
MACKENZIE_IN	2 - 7	0.576	0.0022	0.0197
Site #1_IN	0 - 2	2.840	0.0405	0.0904
Site #1_IN	2 - 7	0.445	0.0454	0.0219
Site #1_OUT	0 - 2	0.568	0.0011	0.0185
Site #1_OUT	2 - 7	0.277	0.0041	0.0114
Site #2_IN	0 - 4	0.654	0.0123	0.0102
Site #2_IN	4 - 8	0.370	0.0041	0.0129
Site #2_OUT	0 - 5	0.725	0.0145	0.0236
Site #2_OUT	5 - 10	0.272	0.0039	0.0170
Site #2, LOWER	0 - 2	0.866	0.0030	0.0247
Site #2, LOWER	2 - 7	0.206	0.0243	0.0096
Site #3_IN	0 - 3	1.190	0.0034	0.0364
Site #3_IN	3 - 8	0.505	0.0426	0.0222
Site #3_OUT	0 - 3	1.380	0.0080	0.0450
Site #3_OUT	3 - 8	0.524	0.0054	0.0197
BALLANTYNE_IN	0 - 3	1.010	0.0058	0.0328
BALLANTYNE_IN	3 - 8	0.429	0.0015	0.0191

Table 4.4. TDS, K+, NO3- and pH of soil samples within (In) and Outside (Out) of the Mushroom patches.

Location	**Number**	**In**	**Out**	**TDS**	**K +**	**NO - 3**	**PH**
Site #1	5115-01	Bm 2-7cm		10 (0)	1	11	4.49
	5114-01	Ae 0-2cm		20	3	9	3.89
	5117-01		Bm 2-7cm	0	0	12	4.32
	5116-01		Ae 0-2cm	0	0	12	4.02
Site #2	5118-01	Ae 0-4cm		0	1	11	4.45
	5119-01	Bm 4-8cm		0	0	9	4.72
	5120-01		Ae 0-5cm	10	2	11	4.26
	5121-01		Bm 5-10cm	0	1	14	4.87
	5122-01		Ae 0-2cm	10	2	15	4.46
	5123-01		Bm 2-7cm	0	1	13	5.09
Site #3	5124-01	Ae 0-2cm		10	3	12	4.46
	5125-01	Bm 2-7cm		10	2	17	4.86
	5126-01		Ae 0-3cm	10	2	17	4.69
	5127-01		Bm 3-8cm	10	1	16	4.74
Meeyomoot	5106-01	Ae0-1.5cm		10	2	14	5.11
Meeyomoot	5107-01	Bm1.5-5		0	0	11	4.49
Meeyomoot	5108-01		Ae0-1.5cm	10	1	13	4.31
Meeyomoot	5109-01		Bm 1.5-5	0	0	14	4.36
ballan.Riv.	5128-01	Ae 0-3cm		0	0	14	4.74
ballan.Riv.	5129-01	Bm 3-8cm		0	0	14	4.89
Remay #4	5100-01	0-5cm		10	3	12	4.62
Remay #4	5101-01	5-10cm		0	2	11	4.79
Remay #4	5102-01	10-15cm		0	0	10	4.84
Remay #4	5103-01		0-5cm	20	2	17	4.92
Remay #4	5104-01		5-10cm	0	1	16	4.85
Remay #4	5105-01		10-15cm	0	0	15	4.65
Bear River	5110-01	Ae 0-2cm		20	2	34 (16)	5.06
Bear River	5111-01	Bm 2-7cm		10	0	67 (15)	5.1
mack.Burn	5112-01	Ae 0-2cm		20	2	84 (40)	4.93
mack.Burn	5113-01	Bm 2-7		0	1	81 (31)	5.13

Table 4.5. P-values from Student t-tests comparing carbon, sulphur, nitrogen, TDS, K^+, NO_3^-, and pH of soil samples from within (In) and outside (Out) of mushroom patches.

	A-Horizon*			B-Horizon**		
	Location	Average	p-value	Location	Average	p-value
Total carbon (%)	In	1.3276	0.2571	In	0.4673	0.3441
	Out	0.9176		Out	0.4062	
Total sulphur (%)	In	0.0127	0.4224	In	0.0168	0.1265
	Out	0.0077		Out	0.0046	
Total nitrogen (%)	In	0.4151	0.4401	In	0.0185	0.1961
	Out	0.0300		Out	0.0160	
TDS	In	11.2500	0.7650	In	2.2222	0.7101
	Out	10.0000		Out	1.4286	
K^+	In	2.0000	0.3629	In	0.6667	0.8027
	Out	1.5000		Out	0.5714	
NO_3^-	In	16.0000	0.6696	In	14.3333	0.9858
	Out	14.1667		Out	14.2857	
pH	In	4.6575	0.3044	In	4.8122	0.3770
	Out	4.4433		Out	4.6971	

* A-horizon of soil profile ranged between 0 and 2 to 5 cm below the soil surface.

** B-horizon soil profile ranged between 2 cm and 5 to 10 cm below the soil surface.

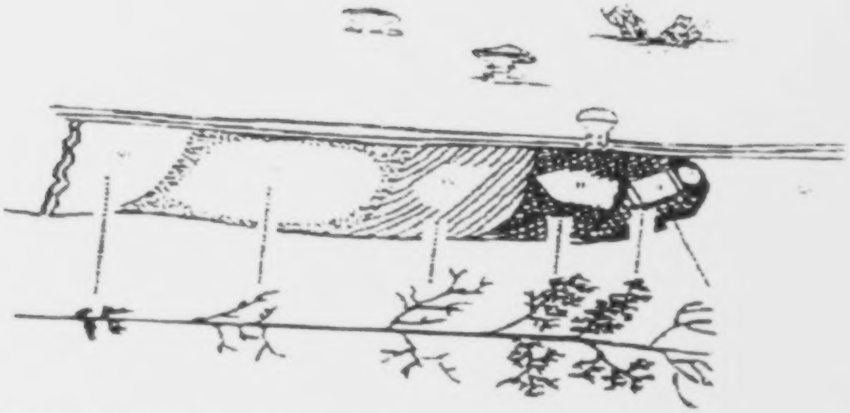
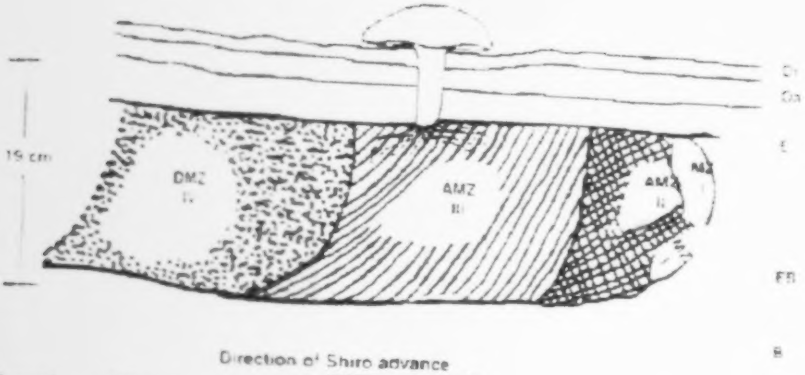


Figure 4.3. Soil profile of the shiro of *Tricholoma matsutake* (Ohara'1981, as cited by Jong, 2004)

0 : zone of roots free from mycorrhizal infection
I : zone of mycelium
II = zone of physiologically active mycorrhizae (next season's AMZ or "active mycorrhizal zone")
III = zone of mycorrhizae for fruiting (AMZ)
IV = zone of decaying mycorrhizae
V = zone of decayed mycorrhizae
VI = zone of sloughed mycorrhizae
VII = zone of soil recovered from mycorrhizal effect



Direction of Shiro advance

Figure 4.4. The shiro profile of a *Tricholoma magnivelare* shiro at site 1, a western hemlock forest type with Douglas-fir and true fir species (Hosford and Ohara, 1995 as cited by Hosford et al., 1997).
MZ 1 = leading edge of mycelium
AMZ = physiologically active mycorrhizal zone
AMZ II = next season's fruiting
AMZ III = present fruiting zone
DMB IV = decaying mycorrhizal zone
Oi = organic, slightly decomposed (duff) layer
Oa = organic, highly decomposed layer
I = soil horizon of maximum eluviation
EB = thin transition layer
B = soil horizon of maximum illuviation

4.1.3 Weather data

The subarctic climate of this Ecoregion is cooler and drier than the Boreal Transition Ecoregion to the south, and the Mid-Boreal Lowland Ecoregion to east. The mean annual daily temperature is 0.3°C. The mean July temperature is 16.3°C, while the mean January temperature is –18.9 °C. The mean annual precipitation is 452 mm, with 291 mm occurring as rainfall between May and September. The short, cool summers result in a typical frost-free period of only 91 days and a total of 1,256 growing degree days (above 5 °C).

Daily weather data of average, minimum, maximum air, soil temperatures, percentage relative humidity, rainfall and average soil moisture readings were taken from May 22 – September 30, 2003 (Appendix Tables 1a-3e) for each of the 3 sites indicated on Figs. 4.1a,b,c,d. However, due to bear damage and tampering, only precipitation data was available for Site 1. While normal rainfall is 323mm, rainfall accumulated between May 22 and September 30, 2003 was below normal at only 175 mm.

Weather stations were purchased and established at each of Sites 1, 2 and 3 (Fig. 4.5). Mushrooms were located within 10 m of the weather station. However, competition with harvesters prevented accurate yield assessment on the meteorological sites. Nevertheless, precipitation, soil moisture, relative humidity (25 cm above soil surface), maximum/minimum and average air (25 cm above soil surface) and 5 cm depth soil temperatures were taken daily beginning May and ending in October in 2001, 2002, 2003, and 2004. This meteorological data was averaged among the three sites for each year. The buyers purchased chanterelles which had been harvested from the same ecoregion as the meteorological stations. Thus, the weather data was then used to correlate yield of chanterelles based on buyer's daily purchase information in each year.

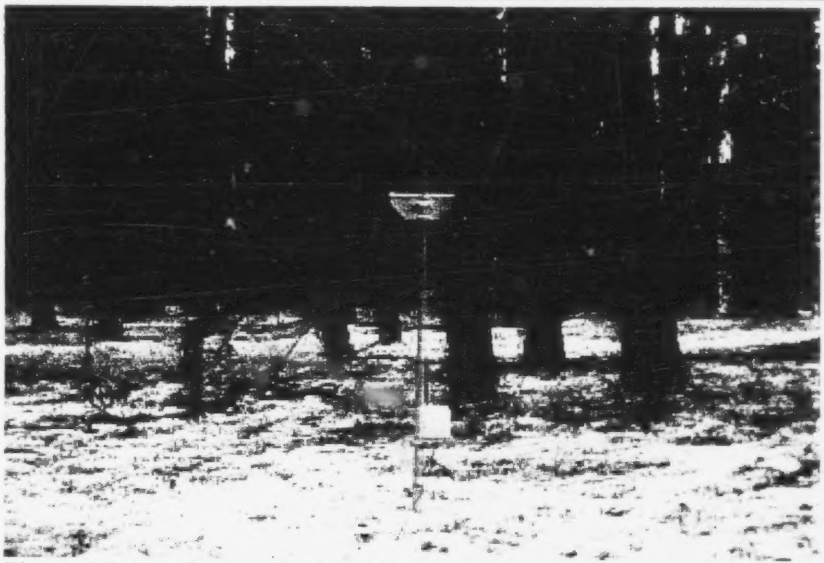


Figure 4.5. Weather station (Site 1): green rain bucket (top of pole), air temperature (°C) & relative humidity (%) (white sensor protector, 25 cm from lichen layer on pole), and soil temperature (°C) & soil moisture (kPa) (black cables attached to sensors 5 cm below soil surface)

4.1.4 Characterization of mushrooms on Sites 1, 2 and 3

In the first year of this study (2001), the main problem was competition with other pickers on the same site (Table 4.6). Mushrooms were not observed on any of the sites until August 9, 2001. Thus, in subsequent years, mushroom harvest data from wholesalers and remote sites for yield were taken. Sites 1, 2 and 3 were only kept for meteorological purposes in 2002, 2003 and 2004.

Table 4.6 Summary of mushroom notes

Date	Site #	Mushroom site description
Aug. 9/01	1	Lots of chanterelles and a few pine mushrooms with the closest mushrooms about 10 m away. Chanterelles were in patches of 1 – 4's and one large patch (> 50) Pine mushrooms in 1's and 2's.
	2	Lots of small patches (1 – 5's) of chanterelles; only one pine
	3	A few pine mushrooms and chanterelles
	4	A few pine mushrooms
Aug.22/01	1	Estimated chanterelle yield: 595 g but harvesting by pickers evident
	2	Mushrooms already harvested by pickers
	3 (new sub-site)	Found 13 pine mushrooms and 5 chanterelle patches Total chanterelle fresh weight = 324 g 23 pines infested, 4 non-infested of all pines harvested
Sept. 11/01	4	Received pine mushrooms from Gerry Ivanochko 7 pines from Remay site: 6 infested (no Remay cover) 1 non-infested (with Remay field cover)

4.1.4.1 Meteorological effects and chanterelle purchase volumes

Warm to hot temperatures 2-4 months prior to fruiting body formation appear to enhance subsequent yield----likely through temperature effects on enhancing fungal growth, hyphae activity and plant assimilates (see Danell, 1994 for a review). This is consistent with Norvell and Roger (1998) who reported a significant correlation between average temperatures and chanterelle abundance where the higher the average summer temperatures (optimum temperature of 68°F), the higher the number of chanterelles. Therefore, the growing degree days (GDD) was plotted for each year and used to correlate with daily purchases 2002, 2003, and 2004 (Tables 4.7-4.16 and Figs. 4.9, 4.10, 4.11). The profile of daily purchases markedly change from one year to the next (Figs. 4.6, 4.7, 4.8). The initiation of the harvest season, peak, duration of the peak and end dates all differ depending on year. Chanterelle season began as early as July 12 in 2003 and as late as early September in 2004. Chanterelle season ended as late as the end of September in 2004 while minimal purchases were made after Sept. 10 in 2002. No clear trends were observed when GDD was compared based on GDD accumulation to harvest, during harvest, from the beginning of harvest to the peak and from the peak to the end of harvest in 2002, 2003 and 2004 (Table 4.12). However, several points are worthy of note:

a) Average temperatures across all sites and years in the period two weeks following harvest were 4.28°C with minimum temperatures averaging –6.8°C (Table 4.13). This contrasts with the period from the beginning to the end of harvest in which average temperatures were 14.1°C with minimum temperatures of –0.6°C.

b) There appeared to be a trend in that based on a 5°C base temperature, GDD accumulation of roughly 790±70 hours coincided with the accumulation of GDD from 6 weeks prior to harvest to the peak of harvest in each of 2002, 2003 and 2004 (Table 4.12, Figs. 4.9, 4.10, 4.11).
c) Altering GDD using various base temperatures of 0, 2, 5, 7, 10, 12, 15°C did not result in higher correlations with yield in either 2002, 2003 or 2004 (Tables 4.7, 4.8, 4.9). However, except for 2003, 6 weeks prior to the start of chanterelle purchase coincided with the point of highest correlation between daily purchase yield and daily GDD (Table 4.10).

This technique of staggering or offsetting the GDD from 0 days (coincides according to calendar date) to 12 weeks (12 weeks prior to the beginning of purchase) aimed to determine the important timeline prior to initiation of harvest when GDD may be important. The GDD accumulated from 6 weeks prior to the initiation of harvest to harvest was 561, 417, 422 in 2002, 2003 and 2004, respectively with average GDD of 13.4, 9.9 and 10.1 °C (Table 4.11). Soil temperatures accumulated were 562, 494, 532 in 2002, 2003, and 2004, respectively with average soil temperatures of 13.4, 11.8 and 12.7°C. There was also no clear trend in the GDD or soil temperature at the 6th week prior to the initiation of chanterelle purchases (Table 4.11).

d) Multiple linear regression analysis using GDD + soil temperature + either soil moisture or precipitation provided the highest regression value when dates were offset between 6 – 13 weeks prior to the initiation of harvest (Tables 4.14, 4.15, 4.16). Thus, it appears that a combination of meteorological factors and not simply temperature are acting to induce chanterelle fruiting body appearance.

e) An accumulation of roughly 530 ± 35°C soil temperature consistently coincided with the start of chanterelle purchases in each of 2002, 2003 and 2004 seasons (Table 4.12, Figs. 4.15, 4.16 and 4.17). Longer term studies are required to determine if this trend and the 790±70 GDD could be used as a predictor of chanterelle mushroom season.

Excessive rain 7-14 days prior to fruiting body formation appears to reduce production (Eveling et al., 1990). Norvell and Roger (1998) reported their 1986-1992 weather data showed little significant correlation between precipitation and chanterelle presence. However, coarse woody debris and canopy cover appeared to be important for chanterelle fruiting body production during low precipitation periods. Similarly in our study, no clear trend was evident between chanterelle yield and precipitation. By the beginning of the chanterelle season, 60, 50 and 100 mm of precipitation had accumulated in 2002, 2003 and 2004, respectively (Figs. 4.12, 4.13, 4.14). Similarly, no clear correlation was evident between daily purchase yield and rainfall patterns in 2002, 2003 and 2004 (Tables 4.7, 4.8, 4.9).

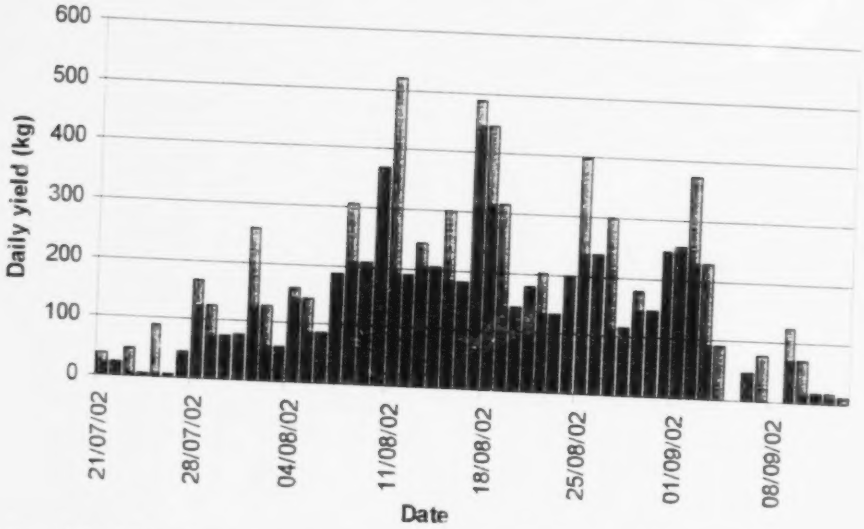


Figure 4.6. 2002 Chanterelle daily harvest over time, based on daily purchases of two major buyers of chanterelle mushrooms.

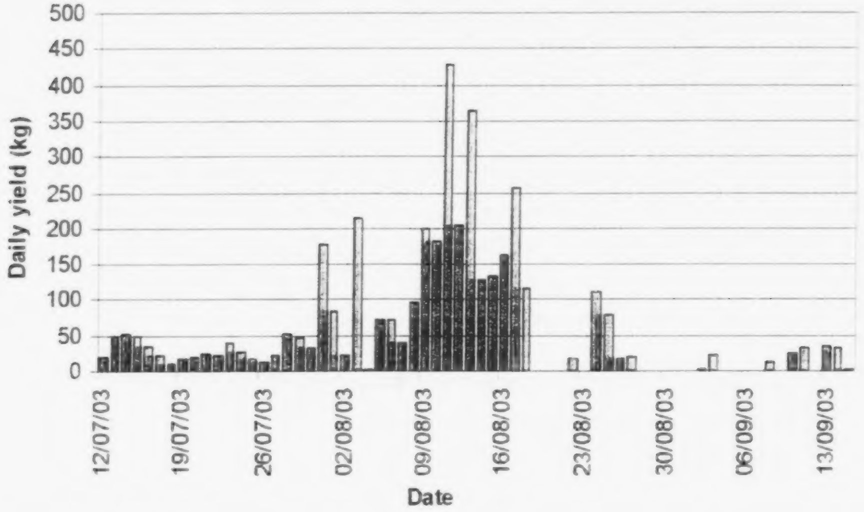


Figure 4.7. 2003 Chanterelle daily harvest over time, based on daily purchases of one major buyer of chanterelle mushrooms.

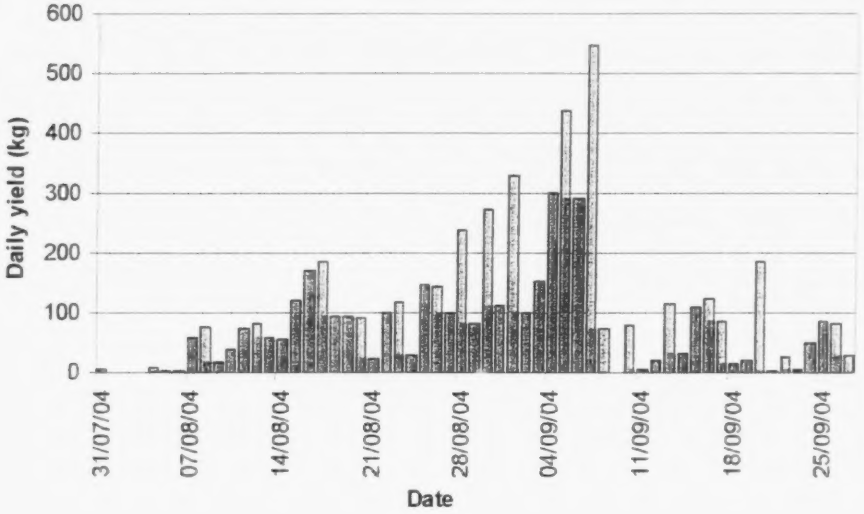


Figure 4.8. 2004 Chanterelle daily harvest over time, based on daily purchases of one major buyers of chanterelle mushrooms.

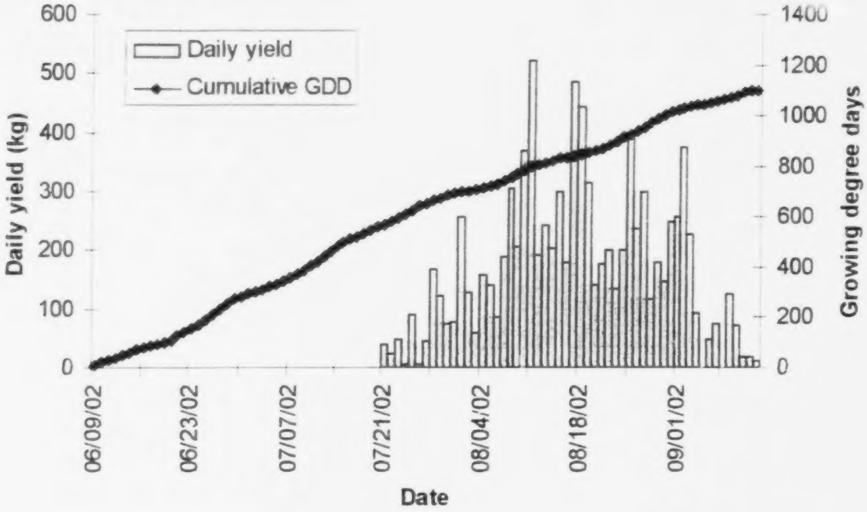


Figure 1.9. 2002 Chanterelle daily harvest and cumulative growing degree days (5°C base temperature) from the period six weeks prior to first harvest to harvest completion.

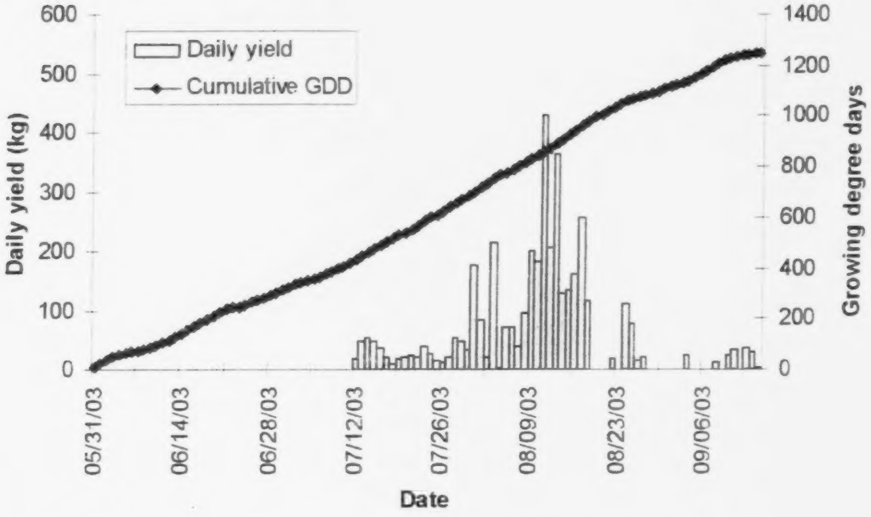


Figure 4.10. 2003 Chanterelle daily harvest and cumulative growing degree days (5°C base temperature) from the period six weeks prior to first harvest to harvest completion.

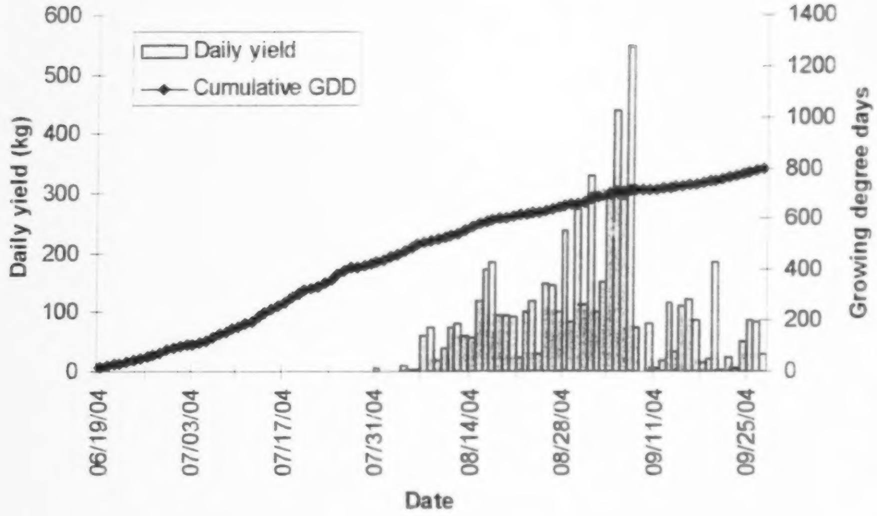


Figure 4.11. 2004 Chanterelle daily harvest and cumulative growing degree days (5°C base temperature) from the period six weeks prior to first harvest to harvest completion.

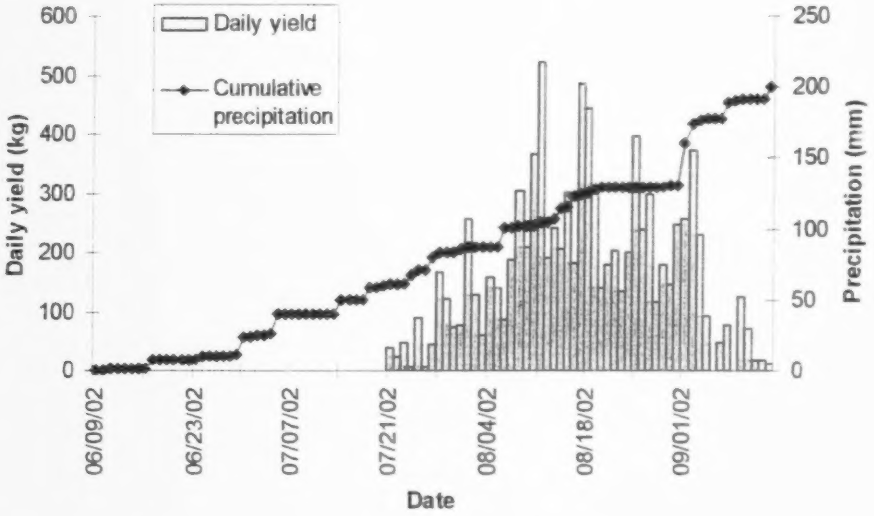


Figure 4.12. 2002 Chanterelle daily harvest and cumulative precipitation from the period six weeks prior to first harvest to harvest completion.

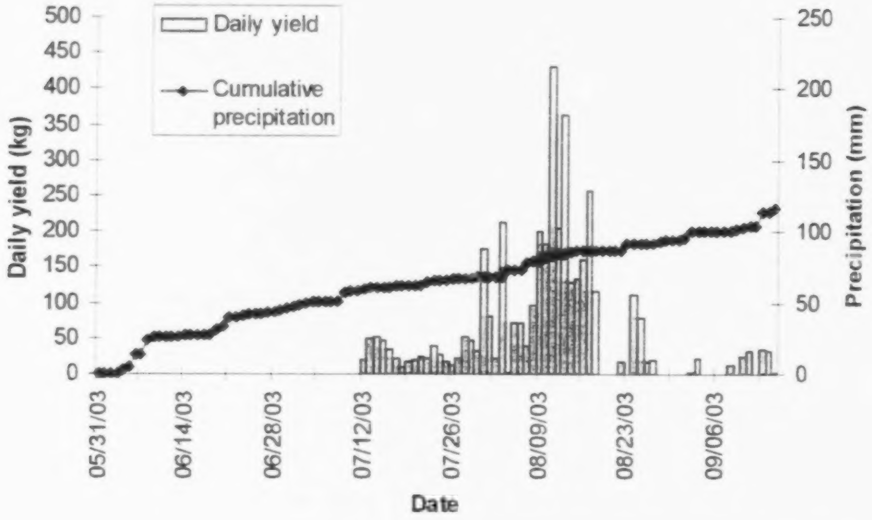


Figure 4.13 2003 Chanterelle daily harvest and cumulative precipitation from the period six weeks prior to first harvest to harvest completion.

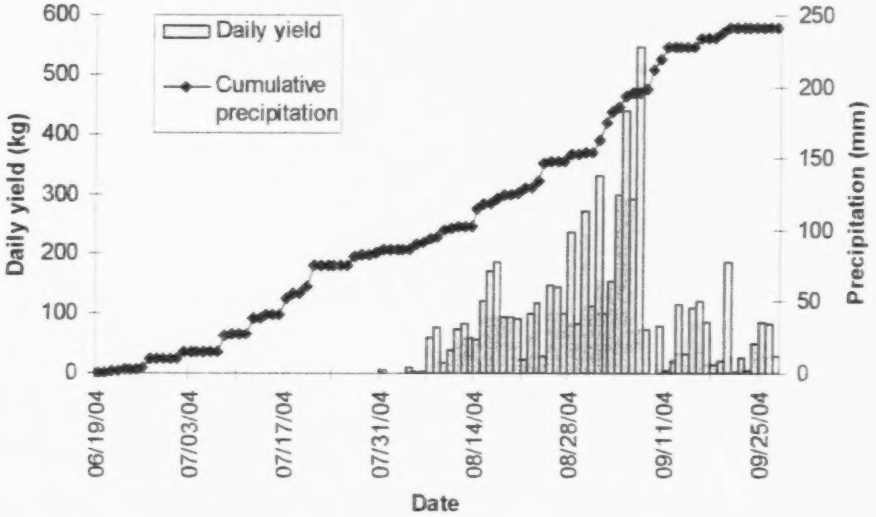


Figure 4.14. 2004 Chanterelle daily harvest and cumulative precipitation from the period six weeks prior to first harvest to harvest completion.

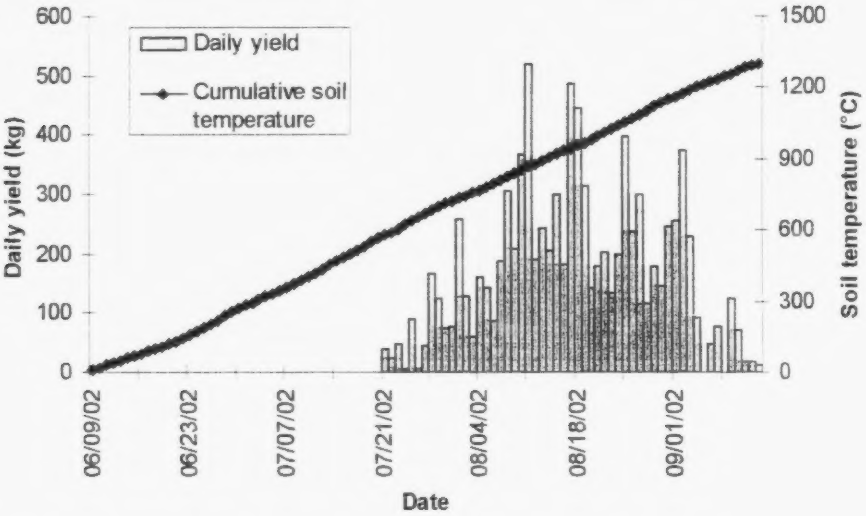


Figure 4.15. 2002 Chanterelle daily harvest and cumulative soil temperature from the period six weeks prior to first harvest to harvest completion.

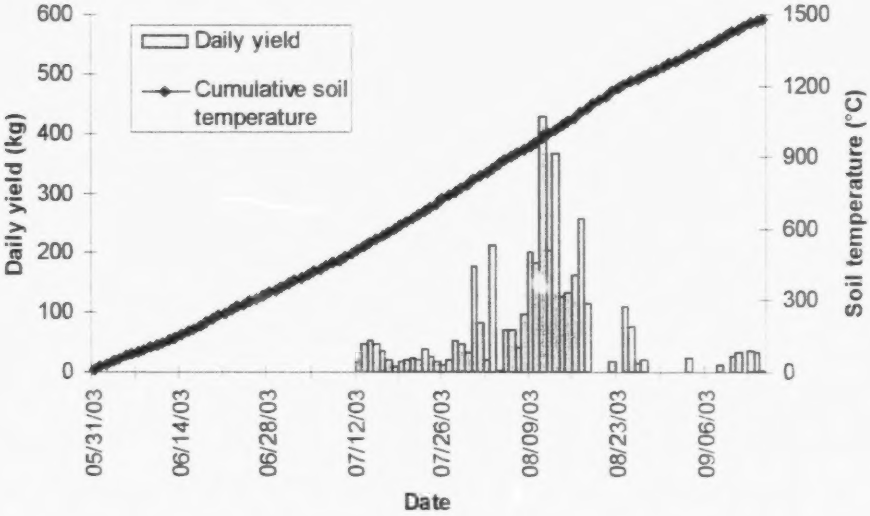


Figure 4.16. 2003 Chanterelle daily harvest and cumulative soil temperature from the period six weeks prior to first harvest to harvest completion.

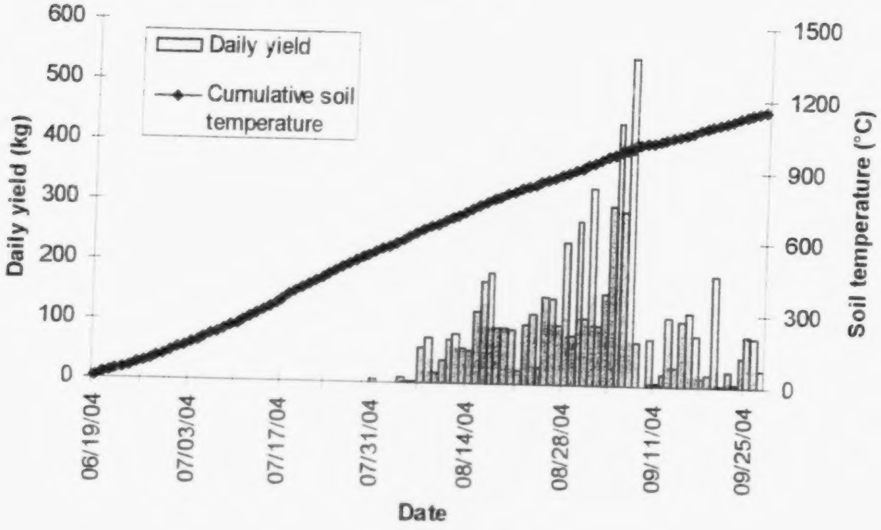


Figure 4.17. 2004 Chanterelle daily harvest and cumulative soil temperature from the period six weeks prior to first harvest to harvest completion.

Table 4.7. 2002 Correlation coefficients correlating Chanterelle daily yield with growing degree days (GDD) at varying base temperatures, humidity (HMD), rainfall (RNF), and soil moisture SMB), for time period during harvest (21/07/2002 – 13/09/2002).

	GDD (0°C)	GDD (2°C)	GDD (5°C)	GDD (7°C)	GDD (10°C)	GDD (12°C)	GDD (15°C)	Soil Temp	RNF	SMB	HMD
Yield-0 days	0.015	0.015	0.015	0.015	0.006	0.012	-0.024	0.122	0.035	0.193	No Data
Yield-2 days	0.147	0.147	0.147	0.147	0.147	0.154	0.105	0.208	0.059	0.078	No Data
Yield-4 days	0.142	0.142	0.142	0.142	0.140	0.125	0.056	0.119	-0.154	0.074	No Data
Yield-6 days	-0.088	-0.088	-0.088	-0.088	-0.083	-0.094	-0.172	-0.231	-0.245	0.286	No Data
Yield-8 days	-0.268	-0.268	-0.268	-0.268	-0.256	-0.236	-0.243	-0.383	-0.105	-0.013	No Data
Yield-14 days	-0.556	-0.556	-0.556	-0.556	-0.558	-0.556	-0.546	-0.519	0.220	-0.200	No Data
Yield-18 days	-0.117	-0.117	-0.117	-0.117	-0.120	-0.140	-0.137	-0.004	0.175	-0.579	No Data
Yield-21 days	0.035	0.035	0.035	0.035	0.034	0.015	-0.004	0.143	0.085	-0.397	No Data
Yield-28 days	-0.065	-0.065	-0.065	-0.065	-0.065	-0.071	-0.094	0.103	0.107	-0.195	No Data
Yield-6wks	0.277	0.277	0.277	0.277	0.273	0.254	0.209	0.394	0.177	0.175	No Data
Yield-8wks	0.008	0.008	0.008	0.008	0.008	0.000	-0.055	0.095	0.002	0.077	No Data
Yield-10wks	-0.015	-0.015	-0.018	-0.025	-0.070	-0.120	-0.155	0.006	-0.203	0.316	No Data
Yield-12wks	-0.358	-0.358	-0.364	-0.372	-0.361	-0.378	-0.249	-0.594	-0.079	-0.061	No Data

Table 4.8. 2003 Correlation coefficients correlating Chanterelle daily yield with growing degree days (GDD) at varying base temperatures, humidity (HMD), rainfall (RNF), and soil moisture SMB), for time period during harvest (12/07/2003 – 15/09/2003).

	GDD (0°C)	GDD (2°C)	GDD (5°C)	GDD (7°C)	GDD (10°C)	GDD (12°C)	GDD (15°C)	Soil Temp	RNF	SMB	HMD
Yield-0 days	0.421	0.421	0.421	0.421	0.428	0.439	0.457	0.236	0.024	-0.405	-0.209
Yield-2 days	0.337	0.337	0.337	0.337	0.338	0.339	0.319	0.393	0.168	-0.395	-0.132
Yield-4 days	0.180	0.180	0.180	0.180	0.180	0.178	0.129	0.287	0.073	-0.384	-0.060
Yield-6 days	0.116	0.116	0.116	0.104	0.116	0.103	0.066	0.268	-0.028	-0.268	0.037
Yield-8 days	0.244	0.244	0.244	0.246	0.244	0.246	0.230	0.290	0.047	-0.039	0.194
Yield-14 days	0.306	0.306	0.306	0.270	0.306	0.270	0.294	0.233	0.049	0.294	0.370
Yield-18 days	0.102	0.102	0.102	-0.007	0.102	-0.008	0.066	0.068	-0.042	0.079	0.292
Yield-21 days	0.065	0.065	0.065	-0.109	0.065	-0.109	0.047	-0.009	0.025	0.022	0.351
Yield-28 days	-0.127	-0.127	-0.127	-0.297	-0.129	-0.297	-0.151	-0.144	-0.100	-0.235	-0.078
Yield-6wks	-0.252	-0.252	-0.252	0.111	-0.266	0.100	-0.327	-0.135	-0.020	-0.263	-0.140
Yield-8wks	0.082	0.082	0.082	-0.149	0.098	-0.147	0.153	0.013	-0.013	0.357	-0.081
Yield-10wks	-0.022	-0.022	-0.022	-0.343	-0.008	-0.327	0.063	-0.468	-0.033	-0.191	0.044
Yield-12wks	-0.163	0.407	0.407	0.412	0.410	0.423	0.382	-0.329	-0.104	-0.209	-0.395

Table 4.9. 2004 Correlation coefficients correlating Chanterelle daily yield with growing degree days (GDD) at varying base temperatures, humidity (HMD), rainfall (RNF), and soil moisture SMB), for time period during harvest (31/07/2004 – 27/09/2004).

	GDD (0°C)	GDD (2°C)	GDD (5°C)	GDD (7°C)	GDD (10°C)	GDD (12°C)	GDD (15°C)	Soil Temp	RNF	SMB	HMD
Yield-0 days	-0.079	-0.085	-0.110	-0.142	-0.186	-0.208	-0.241	0.046	0.112	-0.359	-0.209
Yield-2 days	0.118	0.110	0.084	0.051	-0.021	-0.069	-0.101	0.158	0.373	-0.396	-0.132
Yield-4 days	0.096	0.094	0.087	0.077	0.041	0.001	-0.028	0.050	0.374	-0.202	-0.060
Yield-6 days	-0.116	-0.119	-0.129	-0.140	-0.156	-0.178	-0.209	-0.076	0.138	-0.006	0.037
Yield-8 days	-0.172	-0.180	-0.209	-0.237	-0.266	-0.269	-0.260	-0.097	0.027	0.033	0.194
Yield-14 days	-0.186	-0.194	-0.220	-0.238	-0.240	-0.232	-0.204	-0.107	0.106	0.137	0.370
Yield-18 days	-0.131	-0.130	-0.135	-0.142	-0.166	-0.185	-0.204	-0.038	-0.074	0.166	0.292
Yield-21 days	0.052	0.049	0.037	0.026	0.006	-0.015	-0.063	0.211	-0.003	0.006	0.351
Yield-28 days	0.027	0.019	0.008	0.001	-0.011	-0.003	0.008	0.156	-0.163	-0.135	-0.078
Yield-6wks	0.464	0.471	0.478	0.477	0.470	0.460	0.436	0.589	0.277	-0.022	-0.140
Yield-8wks	0.121	0.132	0.147	0.153	0.151	0.145	0.140	0.146	-0.146	0.228	-0.081
Yield-10wks	-0.232	-0.216	-0.185	-0.159	-0.125	-0.109	-0.073	-0.210	0.094	-0.066	0.044
Yield-12wks	-0.193	-0.231	-0.295	-0.319	-0.297	-0.268	-0.221	-0.290	0.129	-0.324	-0.395

Table 4.10. Correlation coefficients for all three growing seasons. correlating Chanterelle daily yield with growing degree days (5°C base temperature)

	Correlation coefficient		
	2002	2003	2004
Yield-0 days	0.015	0.421	-0.110
Yield-2 days	0.147	0.337	0.084
Yield-4 days	0.142	0.180	0.087
Yield-6 days	-0.088	0.116	-0.129
Yield-8 days	-0.268	0.244	-0.209
Yield-14 days	-0.556	0.306	-0.220
Yield-18 days	-0.117	0.102	-0.135
Yield-21 days	0.035	0.065	0.037
Yield-28 days	-0.065	-0.127	0.008
Yield-6wks	0.277	-0.252	0.478
Yield-8wks	0.008	0.082	0.147
Yield-10wks	-0.018	-0.022	-0.185
Yield-12wks	-0.364	0.407	-0.295

Table 4.11. Actual. Average and cumulative GDD (5°C base temperature) and soil temperature (°C) for the six week period prior to Chanterelle mushroom appearance.

	2002		2003		2004	
	GDD	Soil temperature (°C)	GDD	Soil temperature (°C)	GDD	Soil temperature (°C)
Average GDD at the 6th wk point ± 3 days	7.9	8.8	9.95	10.3	6.91	11.1
Average	13.4	13.4	9.9	11.8	10.1	12.7
Cumulative	561	562	417	494	422	532

Table 4.12. Comparison of accumulated growing degree days (5°C base temperature), accumulated soil temperature and Chanterelle yield information before fruiting, from harvest start to harvest peak, and from harvest peak to end of the season for the 2002, 2003 and 2004 seasons.

2002

	GDD	Soil temp.	Yield (kg)	T-test* p-value
accumulation six weeks prior to harvest:	569	562		
accumulation during harvest:	540	740		
accumulation from harvest start to peak:	223	291	2608.61	0.041
accumulation from harvest peak to end:	316	450	6686.86	
Total from 6 wks prior to harvest peak	792			
Total yield:			9295.47	

* Harvest values (start to peak, peak to end) compared using Student t-test.

2003

	GDD	Soil temp.	Yield (kg)	T-test* p-value
accumulation six weeks prior to harvest:	435	494		
accumulation during harvest:	832	987		
accumulation from harvest start to peak:	425	469	1723.95	0.868
accumulation from harvest peak to end:	407	517	2198.69	
Total from 6 wks prior to harvest peak	860			
Total yield:			3922.65	

* Harvest values (start to peak, peak to end) compared using Student t-test.

2004

	GDD	Soil temp.	Yield (kg)	T-test* p-value
accumulation six weeks prior to harvest:	431	532		
accumulation during harvest:	385	626		
accumulation from harvest start to peak:	288	455	4226.66	
accumulation from harvest peak to end:	98	171	1696.88	
Total from 6 wks prior to harvest peak	719			
Total yield:			5923.54	

* Harvest values (start to peak, peak to end) compared using Student t-test.

Table 4.13. Minimum, maximum, and average air temperatures (°C) for the periods during and after harvest (14 day period after harvest).

Harvest start to harvest end	2002			2003			2004		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
min	1.0	1.9	1.4	0.1	*	-1.7	-2.7	-2.2	-2.2
max	33.2	33.2	33.6	33.2	*	35.3	27.6	28.7	26
average	14.8	14.9	14.8	17.4	*	17.89	10.9	11.13	10.81
After harvest									
min	-7.7	-5.1	-8.7	-3.6	*	-5.1	-4.6	-12.7	**
max	20.6	20.2	24.1	14.8	*	16.4	24.0	21.3	**
average	6.5	6.7	6.4	5.0	*	4.77	5.5	2.1	**

* Data not recorded during complete harvest period.

** Data not recorded after harvest.

Table 4.14. 2002 multiple regression analysis examining the effects of interaction of growing degree days (5°C base temperature) and other variables on Chanterelle daily yield.

	Interactions					
	GDD + Soil temperature	GDD + Precipitation	GDD + Soil moisture	GDD + Soil temperature + Soil moisture	GDD + Soil temperature + Precipitation	No. of observations (paired data points)
Yield-0	0.2470	0.0431	0.2002	0.3288	0.2489	55
Yield-2	0.2288	0.1751	0.1814	0.2593	0.2328	55
Yield-4	0.1455	0.1893	0.1739	0.1748	0.1896	55
Yield-6	0.4071	0.2886	0.2873	0.4548	0.4399	55
Yield-8	0.4530	0.3118	0.2714	0.4676	0.4554	55
Yield-14	0.5567	0.5730	0.5736	0.5823	0.5785	55
Yield-18	0.2514	0.2002	0.5890	0.5985	0.2751	55
Yield-21	0.2465	0.0960	0.3983	0.4032	0.2472	55
Yield-28	0.3181	0.1159	0.1947	0.3188	0.3181	55
Yield-6wks	0.3955	0.3434	0.3114	0.5518	0.4102	55
Yield-8wks	0.1455	0.0088	0.0817	0.2483	0.1558	55
Yield-10wks*	0.0417	0.2053	0.3356	0.3369	0.2385	52
Yield-12wks*	0.6007	0.3805	0.3718	0.6378	0.6008	38
Yield-13wks*	0.6899	0.3465	0.1671	0.7362	0.7023	31
Yield-14wks*	0.6886	0.3612	0.5362	0.6888	0.6905	24

* Weather data not recorded early enough to pair up with the complete range of the shifted yield data.

Table 4.15. 2003 multiple regression analysis examining the effects of interaction of growing degree days (5°C base temperature) and other variables on Chanterelle daily yield.

	Interactions					
	GDD + Soil temperature	GDD + Precipitation	GDD + Soil moisture	GDD + Soil temperature + Soil moisture	GDD + Soil temperature + Precipitation	No. of observations (paired data points)
Yield-0	0.4635	0.4227	0.5087	0.5319	0.4636	66
Yield-2	0.3934	0.3592	0.4451	0.4750	0.4275	66
Yield-4	0.3074	0.1898	0.3872	0.4522	0.3355	66
Yield-6	0.3365	0.1189	0.2749	0.4109	0.3438	66
Yield-8	0.2902	0.2508	0.2444	0.2903	0.3082	66
Yield-14	0.3144	0.3146	0.4349	0.4568	0.3199	66
Yield-18	0.1113	0.1058	0.1220	0.1440	0.1190	66
Yield-21	0.1537	0.0730	0.0648	0.1646	0.1538	66
Yield-28	0.1449	0.1719	0.2375	0.2382	0.1938	66
Yield-6wks	0.2724	0.2646	0.2925	0.3617	0.2850	66
Yield-8wks*	0.0869	0.0821	0.3603	0.3927	0.0869	61
Yield-10wks*	0.4816	0.0480	0.1910	0.4817	0.4827	47
Yield-12wks*	0.6809	0.4085	0.4620	0.7291	0.6813	33
Yield-13wks*	0.5232	0.6212	0.5308	0.5435	0.6225	26
Yield-14wks*	0.3808	0.3499	0.4439	0.4472	0.3858	19

* Weather data not recorded early enough to pair up with the complete range of the shifted yield data.

Table 4.16. 2004 multiple regression analysis examining the effects of interaction of growing degree days (5°C base temperature) and other variables on Chanterelle daily yield.

	Interactions					
	GDD + Soil temperature	GDD + Precipitation	GDD + Soil moisture	GDD + Soil temperature + Soil moisture	GDD + Soil temperature + Precipitation	No. of observations (paired data points)
Yield-0	0.2942	0.1692	0.3623	0.4368	0.2958	62
Yield-2	0.1703	0.3974	0.4242	0.4452	0.4027	62
Yield-4	0.0919	0.3967	0.2359	0.2373	0.4097	62
Yield-6	0.1394	0.1747	0.1286	0.1394	0.1782	62
Yield-8	0.2584	0.2091	0.2099	0.2590	0.2605	62
Yield-14	0.2852	0.2352	0.2368	0.3052	0.2914	62
Yield-18	0.2280	0.1679	0.1870	0.2712	0.2573	62
Yield-21	0.3848	0.0369	0.0411	0.3933	0.3906	62
Yield-28	0.2824	0.1630	0.1360	0.2895	0.3759	62
Yield-6wks	0.5932	0.5327	0.4865	0.6059	0.6050	62
Yield-8wks	0.1560	0.1932	0.2926	0.2934	0.2084	62
Yield-10wks*	0.2160	0.1939	0.2043	0.2255	0.2366	58
Yield-12wks*	0.3554	0.2964	0.3988	0.3988	0.3571	44
Yield-13wks*	0.3700	0.2820	0.1495	0.3868	0.4347	37
Yield-14wks*	0.5081	0.0503	0.2345	0.5877	0.5109	30

* Weather data not recorded early enough to pair up with the complete range of the shifted yield data.

4.1.4.2 Meteorological effects on Pine Mushroom Fruiting Body Formation

In 2002, the first Pine mushrooms came from north of La Ronge (Johnson River) on August 1 (Fig. 4.18). The first pine mushrooms from south of La Ronge (Meeyomoot) were purchased on August 23rd and August 28th. Did the pines start fruiting further north because of colder day and night temperatures? 90% of the pine mushrooms were harvested from the Johnson River area (north of La Ronge). A lot of the pine mushrooms that were purchased after September 13th came from the Prince Albert area. The pine mushrooms started to fruit in this area after heavy rains in August. Interestingly, soil moisture expressed the highest correlation with chanterelle yield when offset by 8-10 weeks prior to the initiation of harvest (Tables 4.7, 4.8 and 4.9).

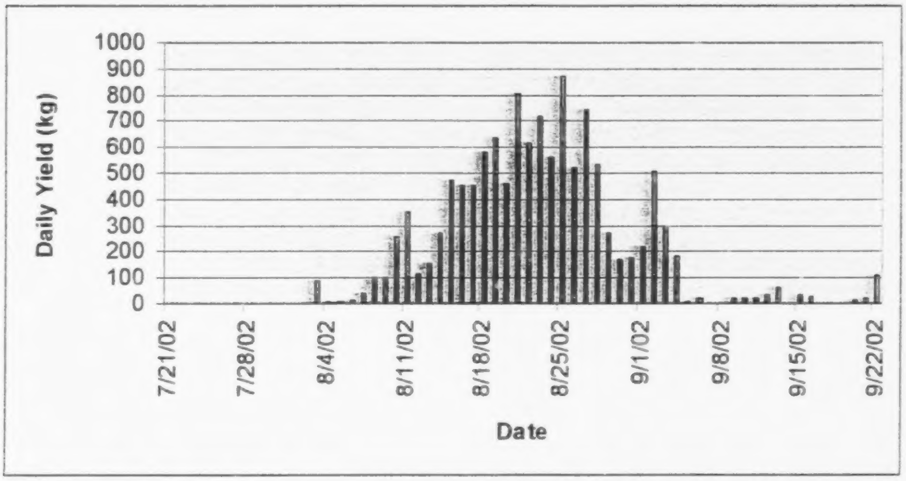


Fig. 4.18. 2002 daily harvest over time, based on daily purchases of five major buyers of pine mushrooms.

The literature considers temperature to be of primary importance to enhance production in matsutake mushrooms (http://user.cavenet.com/akmoore/forecast.html). Cooling is thought to initiate the process of fruit formation, an increase in temperature forms pens (small mushrooms), further cooling begins flush and subsequent warming promotes fruit growth. Alterations to this scenario such as high temperatures, extended cooling period or too low temperatures may limit production. Mushroom patches receiving direct sun also appeared to mature more quickly (http://user.cavenet.com/akmoore/didyouknow.html).

The Japanese matsutake fruiting typically begins soon after the advent of the fall rainy season in a ring centered around the host tree on the AMZ, when soil temperature falls below 19°C (Jong, 2004). However, in Saskatchewan, average daily soil temperatures never reached 19°C (Appendix G) and thus, localized information is important and data based on British Columbia or Pacific Northwest weather data may not be applicable here.

A study conducted by the Pacific Northwest Research Station edible forest mushroom research program (http://user.cavenet.com/akmoore/ewaterstudy.html) indicate moisture influences fruiting body size but not number or timing of mushroom production. However, irrigation was used to trigger fruiting and is considered to act indirectly by lowering temperature.

According to Jong (2004) matsutake fruiting typically ceases when shiro temperatures fall below 10C. However, in Saskatchewan, minimum summer soil temperatures at 5 cm depth can reach 10C in July and August as well as September and in 2002, temperatures did not markedly fall until Sept. 22---over 2 weeks after the end of the pine mushroom season. . Again, data from other regions may not always apply to Saskatchewan conditions. However, weather data from the Johnson River region should be accessed for more accurate temperature information. Potentially, cold-resistant ecotypes of matsutake may be present in Saskatchewan compared to warmer regions of B.C. and Oregon. Based on chanterelle data, chanterelle purchases ended after air temperatures declined to an average of 4.28C and average minimum temperature of –6.8°C (Table 4.13). DNA fingerprinting (Tricholoma species are now available in GenBank (National Center for Biotechnology: www.ncbi.nlm.nih.gov)) could be used to identify ecotypes of Saskatchewan vs. British Columbia for *Tricholoma magnivalere* and *Cantharellus cibarius*.

4.2 Chanterelle mushroom yield estimates

Yield estimates based on sampling from remote regions:

Table 4.17. Chanterelle Harvest Yield from remote sites in 2002, 2003, 2004.

Year	Area (ha) and Yield kg/ha (lb/ac)	Date	Nipekamew kg (lb)	Bow River* kg (lb)
2002		Aug. 26		12.8 (28.4)
		Sept. 5	4.6 (10.2)	
		Sept. 9	11.2 (24.7)	
		Sept. 10	20.5 (45.4)	
		Sept. 12	36.7 (81.3)	
		Total	73.0 (161.6)	12.8 (28.4)*
	Area harvested		26.0 ha	11.33 ha
	Yield		2.71 kg/ha (2.39 lb/ac) (3.57 kg/ha on strip plot)	1.13 kg/ha (0.995 lb/ac) (2.82 kg/ha on strip plot)
2003				**Nipekamew Far North plot**
		July 31	2.73 (6)	
		Aug. 9	4.55 (11)	
		Aug. 16-23	10.42 (25.5)	
		Sept. 11	9.37 (18)	3.41 kg (7.5 lb)
		Oct. 2	6.94 (14.3)	
		Total:	34.01 kg (96.4 lb)	
	Area harvested		26.9 ha	10.5 ha
	Yield		1.26 kg/ha (1.11 lb/ac)	0.325 kg/ha (0.286 lb/ac)
2004		Aug. 20	7.62 (16.76)	
		Aug. 27	0.34 (0.75)	3.64 (8.0)
		Sept. 23	11.68 (25.7)	
		Total	19.64 (43.21)	
	Area harvested		26.9 ha	10.5 ha
	Yield		0.73 kg/ha (0.64 lb/ac)	0.347 kg/ha (0.306 lb/ac)
			BOREAS Weather station (stand #1150)	**BOREAS** West Plot (stand # 1150)
		Sept. 14	3.5 (7.7)	0.95 (2.09)
		Sept. 16	4.56 (10.0)	18.37 (46.4)
		Total	8.06 (17.7)	19.32 (42.5)
	Area harvested		4.8 ha (12 ac)	5.9 ha
	Yield		1.68 kg/ha (1.48 lb/ac)	3.27 kg/ha (2.88 lb/ac)

*Bow River is an extremely remote area and very difficult to access. Weekly yield harvest was difficult to perform

Table 4.18. Pine mushroom yield on remote site in 2002, 2003, 2004.

Year		**Date**	**Nipekamew Kg (lbs)**	**Nipekamew Far North Plot Kg (lbs)**
2002			Few pine mushrooms, low quality	
2003		Sept. 4	1.38 (5)	.450 (1.0 lb)
		Sept. 11	1.26 (2.8)	
		Oct. 2	0.72 (1.6)	
		Total	3.36 (7.39)	
	Area harvested		26.9 ha	10.5 ha
	Yield		.245 kg/ha (.217 lb/ac)	.023 kg/ha (.020 lb/ac)
2004		Aug. 20	0.270 (0.6)	
		Aug. 27		0.91 (2.0)
			BOREAS Weather Station	**BOREAS West Plot**
		Sept. 16	2.34 (5.15)	

Chanterelle yields varied widely between years from 0.73 kg/ha (2004) to 1.26 kg/ha (2003) to 2.71 kg/ha (2002). Calculations of chanterelle and pine mushroom yield and value per hectare will require several more years of data collection in order to more accurately evaluate the true value of this renewable resource.

A rapid estimation of chanterelle fruiting body yield was developed (Fig. 4.19).
Regression analysis of chanterelle fresh weight as a function of cap and stem diameter: Cap diameter best predictor of fresh weight: stem diameter adds very little to the model and by itself is a very poor predictor (R^2 = 59.7%)

Regression equation: fw = -4.15 + 0.283cap diam.: R^2 = 87.6%

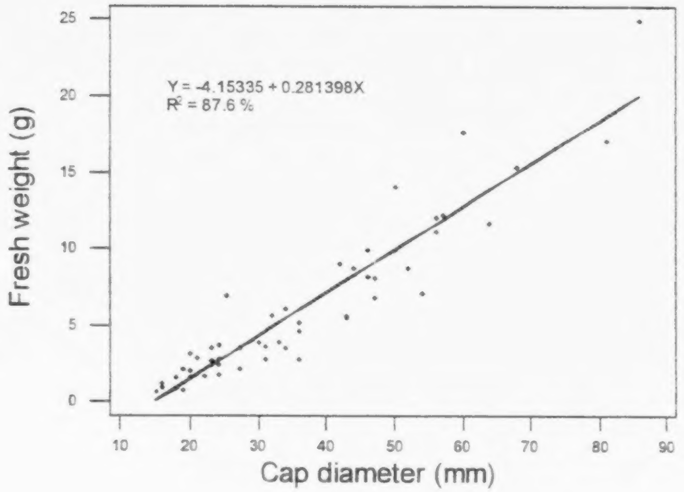
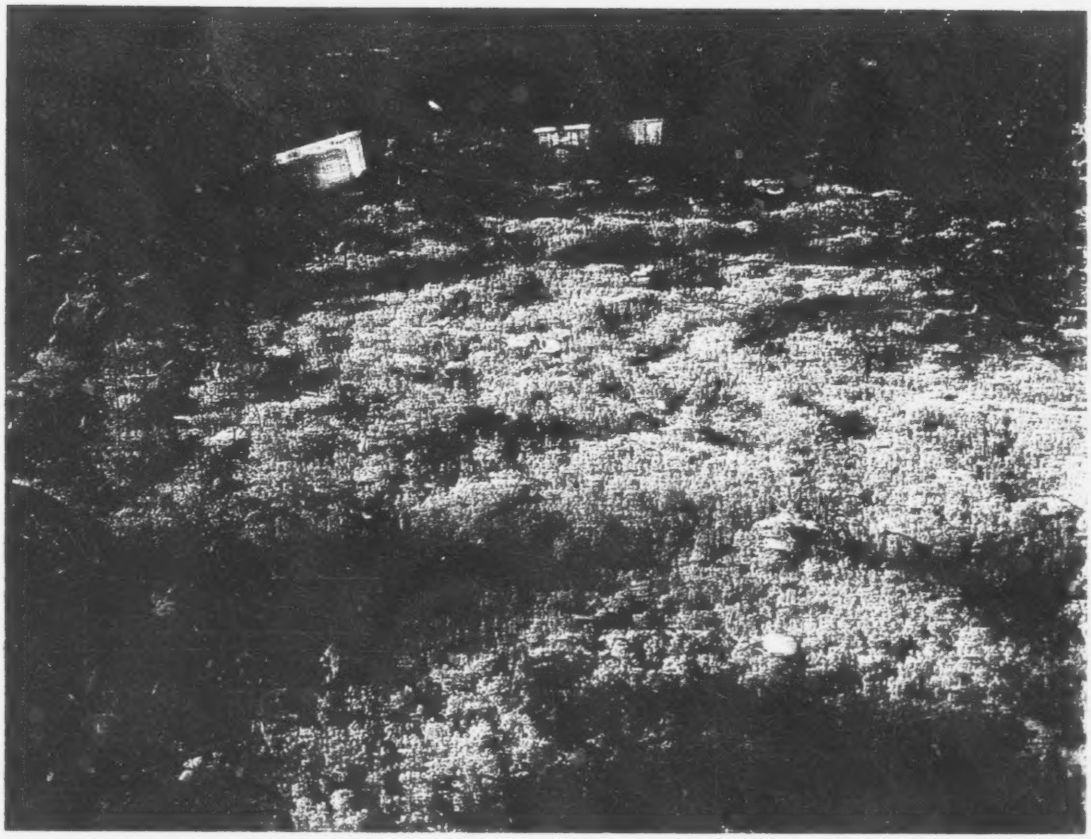


Figure 4.19. Regression analysis reveals that chanterelle cap diameter is a good predictor of fresh weight and could be used as a non-destructive estimation of yield.

Fig. 4.20 Chanterelle mushroom patch at the Nipekamew River



4.3 Survey of chanterelle and pine mushrooms

A reconnaissance survey was conducted on 106 stands in 2002 and 83 stands in 2003 based on stand age, density, and tree species. Specifically, four stand ages (<20 years, 20-40 years, 40-60 years, and >60 years), 2 densities (A/B and C/D) and 2 species (Jack Pine, Jack Pine/Black Spruce) were surveyed for the presence of chanterelle and pine (matsutake) mushrooms. In 2002 and 2003, both chanterelle and pine mushrooms were observed in higher quantities in pure Jack Pine stands compared to Jack Pine/Black Spruce mixtures (Tables 4.20, 4.21). Furthermore, consistently between the two years, incidents of chanterelle mushrooms were greatest in pure Jack pine of density A-B and stand age 41-60 years. Pine mushroom productivity was lower but generally fit this trend. Notably, chanterelle and pine mushrooms were recorded in very young stands of < 20 years of age. In contrast to our study, the mushrooms in British Columbia are often associated with 60- to 200-year old lodgepole pine, western hemlock, Douglas fir, white bark pine and Subalpine fir forests (Jong, 2004b). Thus, it is important to obtain specific information based on region to allow for these differences. Similar to our study, the canopy is often partially open with the timber of marginal value due to disease or poor growing conditions. Soils under mushrooms are generally well or rapidly drained and are normally drier than the average for the area.

Pine mushrooms are difficult to find because they are found beneath the litter/lichen layer (Fig. 4.21). By the time of emergence, quality normally has declined to #3 with #1 of highest quality to #5 (Fig. 4.22).

The bright orange/yellow colour of the chanterelle mushrooms render it more prominent in the lichen layer (Fig. 4.23). Insect pests do not appear to affect chanterelle mushrooms but colour and freshness are 2 quality criteria (Fig. 4.24).

In the U.S. Pacific Northwest, American pine mushroom usually occurs in stands of trees 100 to 200 years old, with multiple tree species including lodgepole pine, Douglas fir or western hemlock as the dominant overstory species (Jong, 2004b). In southwestern Oregon and along the coast of California it appears with tanoak and madrone. Further north in central Washington and Oregon it most often is found in mixed stand of conifers. By contrast in our study, pine mushrooms were observed in stands as young as < 20 years of age and in predominantly pure Jack Pine areas. Thus, it is important to perform studies in the regions of specific interest. Information from one ecologic area may not able to be applied to another.

Table 4.20. Occurrences of Chanterelle and Pine Mushrooms 2002

Jack Pine Stands

	Stand Density A-B			Stand Density C-D		
Stand Age (years)	Chanterelles	Pines	No. of Stands	Chanterelles	Pines	No. of Stands
< 20	1	1	9	2	1	11
21-40	2	1	3	3	3	6
41-60	13	4	16	4	1	6
> 60	3	0	6	5	2	8
Total No. Stands			34			31

Jack Pine/Black Spruce Stands

	Stand Density A-B			Stand Density C-D		
Stand Age (years)	Chanterelles	Pines	No. of Stands	Chanterelles	Pines	No. of Stands
< 20	0	0	4	0	0	9
21-40	0	0	1	1	1	3
41-60	5	2	5	4	0	7
> 60	2	1	5	1	5	7
Total No. Stands			15			26

Table 4.21. Occurrences of Chanterelle and Pine Mushrooms 2003

Jack Pine Stands

	Stand Density A-B			Stand Density C-D		
Stand Age (years)	Chanterelles	Pines	No. of Stands	Chanterelles	Pines	No. of Stands
< 20	0	0	6	0	0	8
21-40	1	0	2	3	0	5
41-60	12	1	14	3	0	5
> 60	9	0	10	4	0	7
Total No. Stands			32			25

Jack Pine/Black Spruce Stands

	Stand Density A-B			Stand Density C-D		
Stand Age (years)	Chanterelles	Pines	No. of Stands	Chanterelles	Pines	No. of Stands
< 20	0	0	2	0	0	0
21-40	0	0	0	1	0	2
41-60	3	0	3	4	1	7
> 60	1	0	4	4	0	8
Total No. Stands			9			17

Note: the inventory of 2003 recorded very few pine mushrooms because the survey was conducted before the pine mushroomshad begun fruiting.

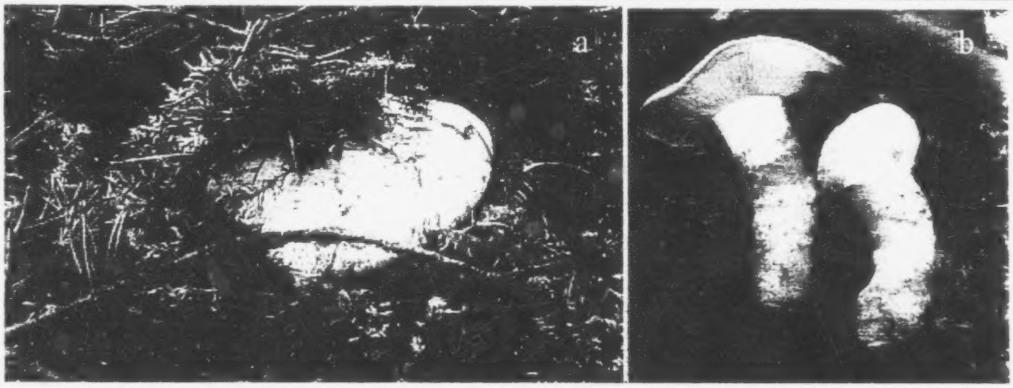


Figure 4.21. Pine mushrooms are difficult to find because they are formed below the litter/lichen layer. By the time they emerge, most are at best #3. (a) Emerging pine; and (b) pine mushrooms dug up. Note bottom 5 – 7 cm of stem is covered in sand indicating depth where mushrooms begin development.

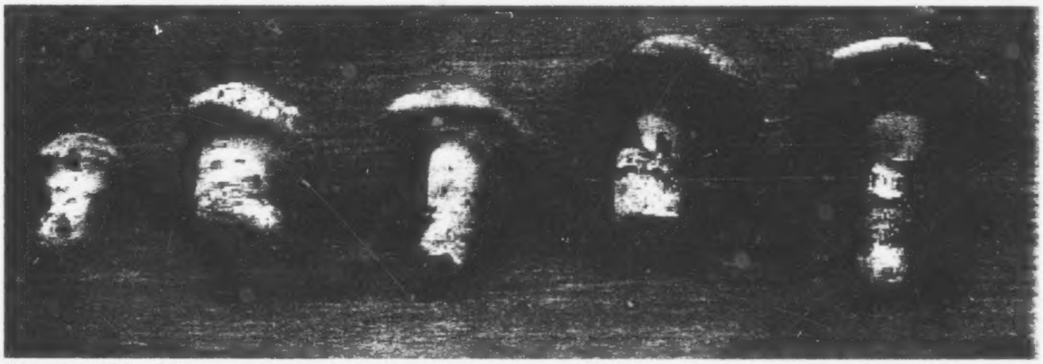


Figure 4.22. Pine mushroom harvested on August 22 2001. From left to right quality ranges from #1 (veil intact), #2 (veil starting to part slightly), #3 (holes in veil), #4 (veil is greatly compromised) and #5 (veil is completely missing)

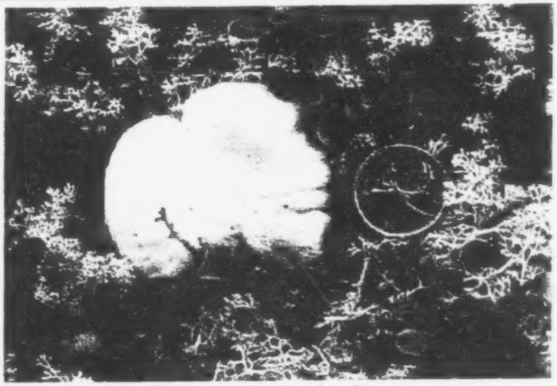


Figure 4.23. Chanterelle in the forest. Chanterelles stand out from the lichen/litter layer better than pines. Quality is not affected by the same factors as pine mushroom. Colour and freshness are important.

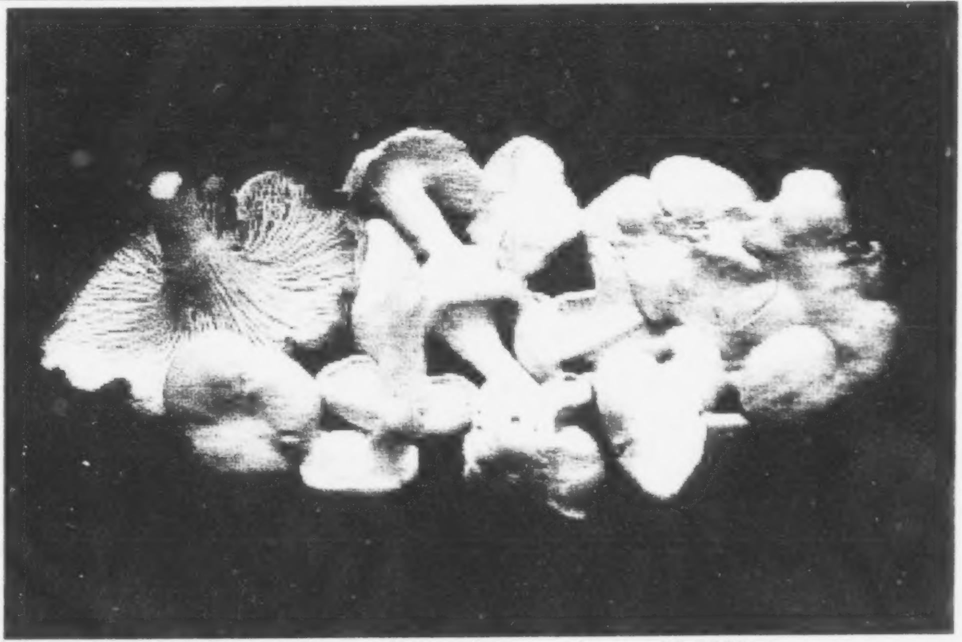


Figure 4.24. Grouping of chanterelle mushrooms (August 22 2001)

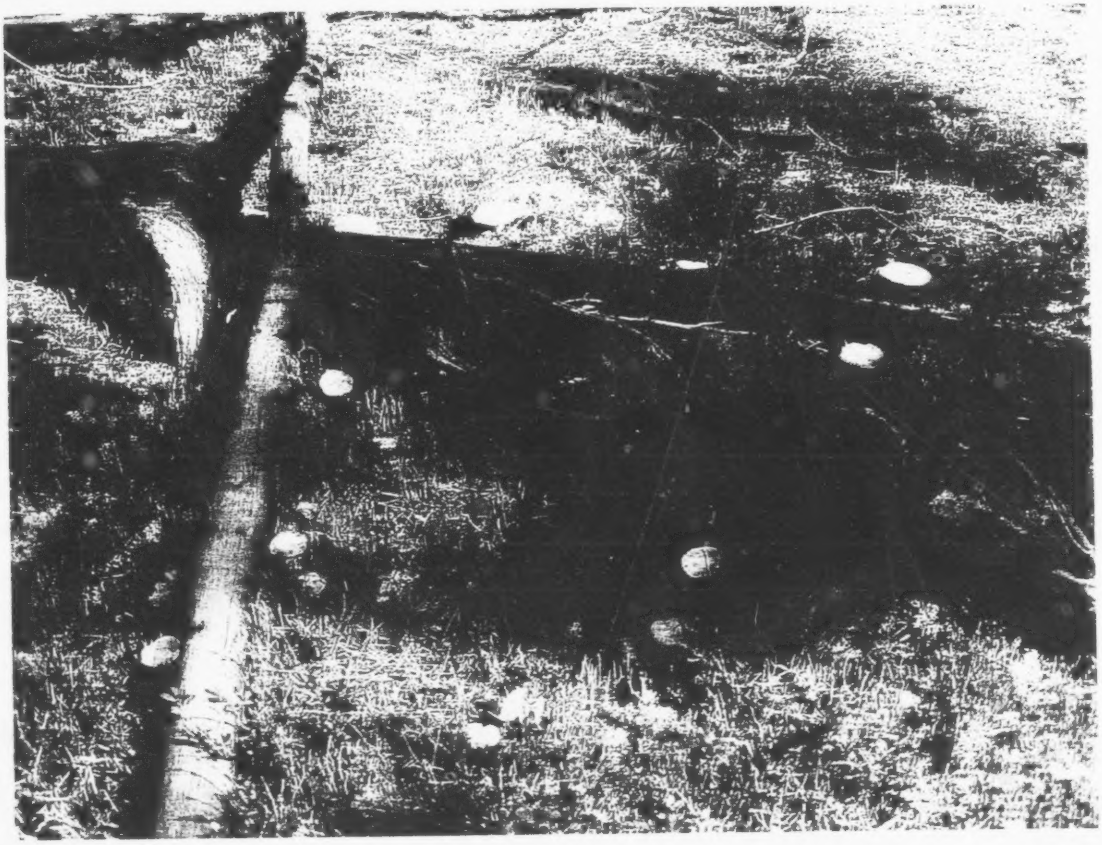


Fig. 4.25 Young, 20 year old stand of pure Jack Pine with chanterelle mushrooms

4.4 Sustainability

4.4.1 Sporulation and chanterelle mushrooms

Initially, the determination of *Cantharellus cibarius* developmental stage associated with release appeared to be a viable approach to maintain long-term sustainability of this chanterelle mushroom crop. However, additional information suggests no negative impact of picking mature fruiting bodies on subsequent production. In fact, delayed harvest of chanterelle mushrooms will decrease productivity on the same site within a given year. Multi-flush production will be reduced if chanterelle harvest is delayed (Danell, 1994), specifically, harvest should occur before the pileus becomes flattened. It is unrealistic to expect harvesters to leave a certain percentage of mature mushrooms for sustainability purposes. Markets will determine which mushrooms are harvested and since pickers are paid by the pound, the larger, mature mushrooms are more likely to be taken.

Nevertheless, ample evidence from Europe with a longer history of chanterelle harvest indicates a marked and serious decline in wild mushroom production and in the Netherlands, *Cantharellus cibarius* has declined by 60% (see Danell, 1994 for a review). Sustainability is associated not only with spore release but with destruction of the natural mushroom growing environment. Mushrooms such as chanterelles which propagate primarily vegetatively through underground hyphae and mycorrhizal associations are especially sensitive. The destruction of the critical surface layers has been associated with:

- trampling by pickers
- clear-cutting (removes mushroom carbohydrate supply, lichen layers which prevent evaporative water loss from the soil).
- removal of logs and other moisture-holding substrates.

Various international experts were consulted by e-mail and their responses are found in Appendix A. In summary,

- ❖ Only *Cantharellus cibarius* mushrooms of cap diameter > 2 cm should be picked.
- ❖ These mushrooms are long-lived (about 84 days) and will continue to produce spores from within 2 weeks of emergence to the end of its life stage (up to 3 months).
- ❖ From 250,000 to 100 million spores are released per mushroom.
- ❖ Best sporulation conditions are warm, dry weather conditions. Sporulation is reduced in wet, cool weather.
- ❖ In Switzerland, harvesters cannot pick between the 1st to the 10th of each month to allow time for sporulation.
- ❖ Picking fruiting bodies will decrease sporulation potential by a factor of 1,000 to 10,000.
- ❖ Chanterelles should be cut, not pulled when picking, although Norvell and Roger (1998) indicate method of harvesting may not make a difference.

4.4.2. Sustainability and pine mushroom harvest

Proper Harvest Techniques

Litter removal, raking, forest floor compaction, picking over mature mushrooms, and timber harvest may all influence matsutake production at the scale of the individual tree or cluster (Jong, 2004a). It should be noted that Saskatchewan pine mushrooms appear in the summer when there is a greater infestation of worms. Therefore, mature Sask. pine mushrooms are usually infested with worms so they are not harvested and therefore sporulation can occur. There is even a problem with immature mushrooms being infested with worms. Therefore, a very small percentage of the crop is actually harvested. Recent research with Oregon American matsutake suggests raking can decrease subsequent production for several years Jong, 2004a). Jong goes onto say, "By using proper harvest techniques listed below, harvesters can get the best possible recovery of matsutake year after year.
1) Pick mushrooms one by one by hand or using special tools;
2) Do not rake or otherwise disturb the forest floor;
3) Pick only the mushrooms that reach optimal size and value;
4) Spread the caps (with spores) of mushrooms that are too old to sell or eat;
5) Do not remove or disturb litter layers where more mushrooms are continuously growing; and
6) Replace all soils and litter to their natural look after harvest.
When a mushroom is found, remove litter and soil covering only the cap, and then place a hand around the cap and wiggle it in a circular motion. Almost all may be harvested using this hand method. In some situations, harvesters are permitted to use only narrow tools (less than 1 inch wide) such as weed poppers for prying mushroom from ground. A variety of methods are used, but most insert the tool in the soil about 1 inch from the mushroom, at a depth just below the bottom of he stem, and then pry up. It is imperative that a tool is used only when the hand method fails."

4.5 Identification of pest species

On three separate harvests in 3 separate regions over 3 separate dates, the percent infested pine mushrooms was:

a) 23 infested out of 27 mushrooms (85%), August 22nd
b) 6 infested mushrooms out of 7 samples (85%) September 11
c) 16 infested pine mushrooms out of 19 samples (84%) September 17

Therefore, this problem is significant and is likely the major factor limiting expansion of the pine mushroom industry. Figure 4.26a illustrates a typical pine mushroom with maggot damage. Fig. 4.26b shows a maggot 8-10 mm long dislodged from the mushroom 10 days after harvest. The maggots when hatched were identified to be from the genus *Drosophiladae* (Fig. 4.27). The species could not be identified by AAFC.

Figure 4.28 pictures the Remay field cover over one suspected shiro at site 4. Sites producing pine mushrooms were identified in 2001. Thus, Remay covers were placed over those sites early in 2002 and the quality of pine mushrooms in terms of freedom from pest damage were assessed during the 2002 season. In spite of the cover, pine mushrooms emerging from beneath the Remay cover harboured both larvae and pupae (Table 4.25). However, initial visual observations of these mushrooms did not indicate any evidence of insect damage (Figs. 4.29, 4.30) and it was only upon 4 weeks of incubation at room temperature that larvae emerged.

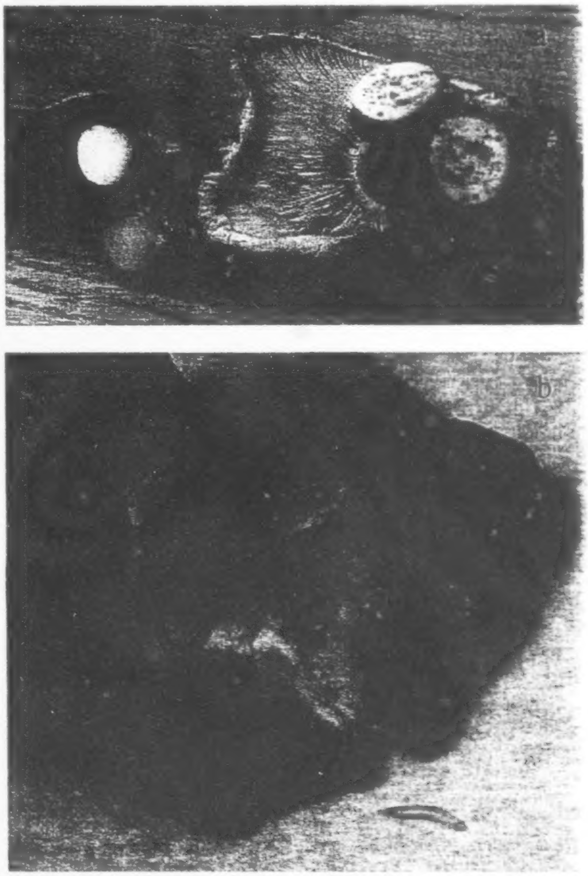


Fig. 4.26.: Pine mushroom with maggot damage. (a) left- mushroom with no damage and right- typical maggot damage at harvest (August 22 2001); and (b) maggot (8 – 10 mm long) dislodged from mushroom 10 days after harvest.

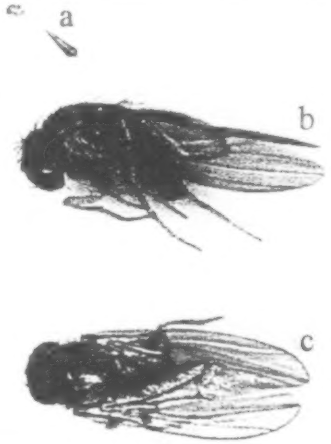


Fig. 4.27.: Small fly hatched from pine mushroom maggot. (a) real size [2 mm long]; (b) side view; and (c) top view

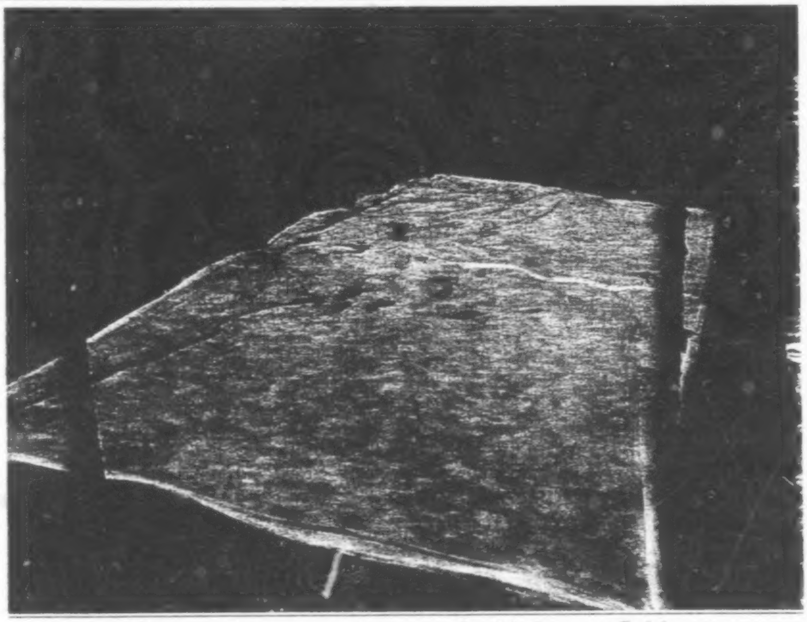


Fig. 4.28. Pine mushroom patch covered with Remay field cover

Table 4.25. Mushrooms incubated for a period of 4 weeks at 24°C.

	Remay site A	**Remay site D**
Number of mushrooms sampled	2	4
Larvae numbers	27	8
Pupae	8	2

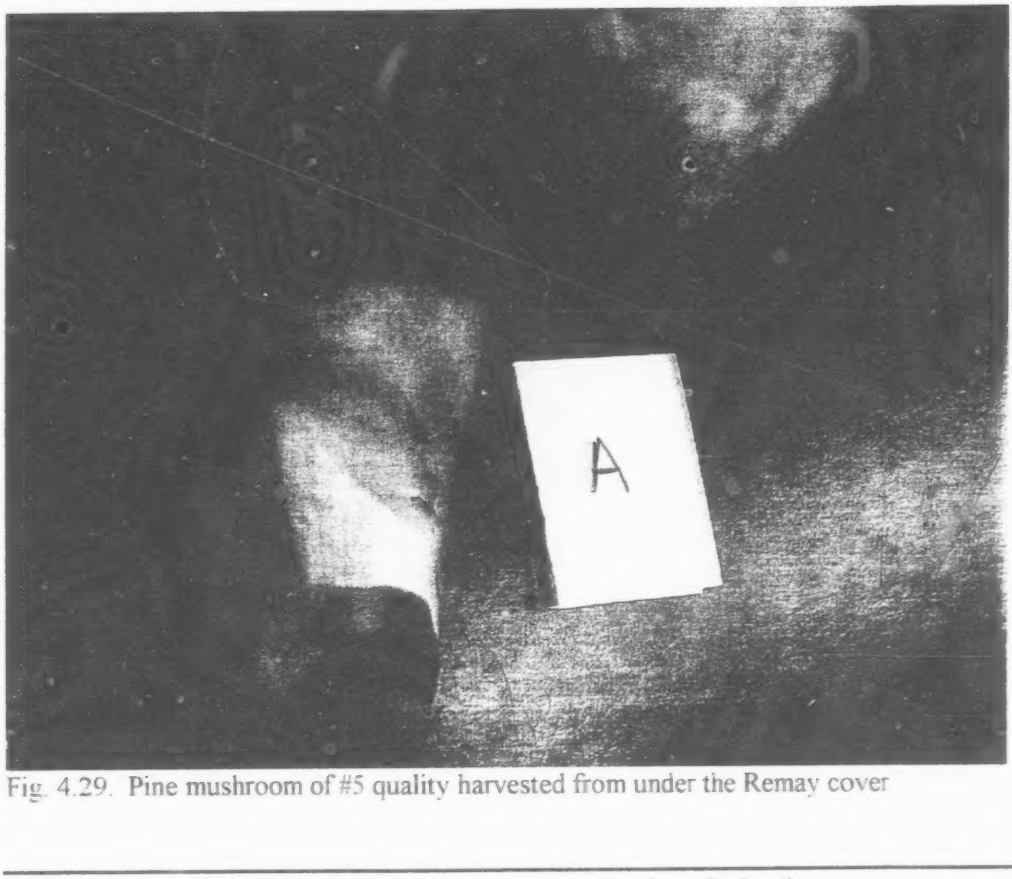


Fig. 4.29. Pine mushroom of #5 quality harvested from under the Remay cover

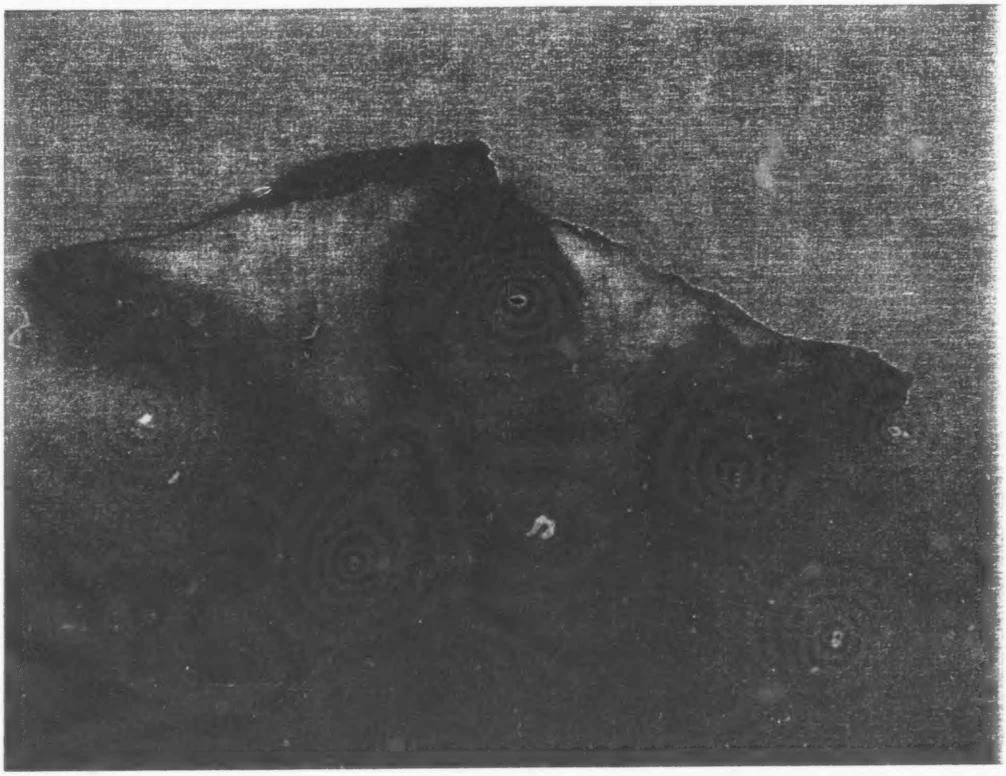


Fig. 4.30 Pine mushrooms harvested from beneath the Remay cover and sectioned both cross-sectionally and longitudinally (no sign of worm damage).

4.6 Development of Knowledge Base

Interviews with buyers enabled the acquisition of the detailed summary of mushroom purchases on a per day basis in section 4.1.1.4 above. This information was only possible through the long-standing relationship cultivated by Gerry Ivanochko. These relationships are extremely important in providing accurate information on yield.

Interviews with pickers were used to identify sites for the inventory.

Cliff Jessup and Gerry Ivanochko observed mushroom production in islands of trees left after a fire. These trees were also of the <20 year range.

Gerry Ivanochko reports and communicates information generated from this study to Weyerhaueser stakeholder committee meetings on an annual basis.

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6.0 Equipment Purchased

3 – Spectrum Watchdog Dataloggers – Model 450
3 – Spectrum External Temperature Probes
3 – WaterMark Granular Matrix (soil moisture) Probes adapted to work with the Watchdog datalogger
3 – Tipping Bucket Rain Collector + Spectrum Event datalogger – Model 115
3 – Radiation shields to protect Watchdog dataloggers
1 – Watchdog data shuttle
3 – Onset Hobo Solar Radiation dataloggers
2 – Timber cruise vests
2 – Suunto 18 inch tree borers
2 – Spinnerette String boxes
3 – Brunton Nexus (Type 15) Compass
1 – Garmin GPS 12 (12 Channel) Personal Navigator
1 – Motorola Model V2260/V2267 digital wireless telephone

7.0 Personnel

Mr. Erl Svendsen was hired as research technician for 2001
Mr. Cliff Jessup, hired on contract to conduct stand survey and yield trials in 2002, 2003 and 2004.

8.0 Appendices

Appendix A

Correspondence 1:

From: Karen Tanino <Karen.Tanino@usask.ca>
Date: Mon, 26 Aug 2002 12:36:41 -0600
To: llnorvell@pnw-ms.com
Cc: "Ivanochko, Gerry" <GIvanochko@agr.gov.sk.ca>
Subject: Chanterelles

Dear Dr. Norvell,
Dr. Susan Kaminskyj suggested I contact you regarding timing of harvest of chanterelles. I believe she has already spoken with you regarding our question. Basically, we are trying to ensure sustainable harvest and hopefully provide some guidelines to pickers such that the fruiting bodies can be picked after sporulation. I understand from Susan that sporulation occurs over a long period of time but basically the larger the fruiting body, the better. She mentioned you had performed tests on determining sustainable harvest age.

Thanks,
Best Regards,
Karen

Dr. Karen K. Tanino
Assoc. Professor
Dept. Plant Sciences,
Univ. of Saskatchewan,
Saskatoon, SK
Canada.

Dear Karen,
As Susan may have told you, I am no longer coordinating the Oregon Cantharellus Study Project, now in its 16th year. The current coordinator is Judy Roger, who is copied here and who may able to supply you with more recent data. However, I believe the current data continue to support the summary I provided in my 1995 paper "Loving the chanterelle to death" (McIlvainea, Journal of the North American Mycological Association).

Essentially, we found that the chanterelle fruit-bodies are very long-lived; consequently they sporulate slowly and remain seemingly viable (i.e. Spore-producing) for up to three months under good conditions. A study by David Largent & David Sime (Humboldt State University, Arcata, California) indicated that chanterelles generally initiate sporulation only after the fruit-body has been above ground for two weeks. What we do not know is the actual age of the chanterelle mycelium, the degree to which an infusion of fresh spores is needed for the existing mycelium to remain viable, or whether chanterelles in the study represent one or several clones/populations. Genetic population studies currently being conducted by Oregon State graduate students may help answer this question.

As you know, chanterelles are ectomycorrhizal partners with forest trees — *Pseudotsuga menziesii & Tsuga heterophylla* at our study site [Our chanterelle is *Cantharellus formosus;* you have a differen t species in Saskatchewan which will have a different set of mycorrhizal photobionts. At the moment, some mycorhizologists suspect that ectomycorrhizal fruiters are not as dependent on sporulation for dispersal as saprophytic fungi are. Thus in retrospect, it is not surprising that our study suggested that chanterelle harvesting may actually stimulate fruit-body production, at least over the short term; [only the first 9 years of data were analyzed for the 1995 paper and the statistical analyses were only preliminary). A number of European mycoecological studies tracking the impact of mild perturbation/disturbance (mushroom harvesting, light timber thinning, etc.) on ectomycorrhizal communities, however, have reached similar conclusions. Since 1976 team of Swiss mycologists (Egli, Ayer, Chatelain, Straatsma) has been conducting a long term observation of the impact of removal of edible fruiting bodies upon subsequent mushroom fruiting and has detected no significant decline in productivity during that time. While in Oslo two weeks ago at the International Mycological Congress, I spoke briefly with one of those mycologists, Dr. Simon Egli, who is currently statistically evaluating OCSP data in preparation for a publication on the Oregon Study. After his more rigorous mathematical analyses of 1986-2001 data, we should have a much clearer picture of the short-term impact of picking at our site.

In the interim, I would recommend that harvesters be advised to harvest only chanterelles >2 cm in diameter and to leave the "over-the-hill" specimens in the field to serve as a spore source. In drafting the OCSP harvest protocols in 1989, I targeted all chanterelles >1 cm for removal in the hopes that ¾1 cm diameter fruiting bodies would not yet have begun sporulating (this seems to have proven to be the case). Also, because I knew that many consumers prefer very small chanterelles for pickling and garnish, and I wanted to see whether removing the fruitbodies at such a young age would have a negative impact. It doesn't **seem** to have, but we'll know more after Dr Egli's final analyses, I hope!
Remember that it's possible that chanterelle mycelium may exist for scores of years, so what impact our study shows still speaks only to the "short term".
After my signature file below and in reverse chronological order, I have included abstracts / summaries of chanterelle-related papers that may provide additional information (these are listed on my web-site). Please feel free to ask Judy or me any questions (note: see Appendix A of this report).

Good Luck!
Lorelei

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President, Pacific Northwest Mycology Service
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Correspondence 2:

Hi Karen --

Actually, when I reread your original query just now, I realized that all you asked for was how best to harvest chanterelles! Susan and I had discussed the Oregon chanterelle study, so I guess that was uppermost in my mind.

Sorry about the huge information "dump". You might find it helpful, but I think perhaps the best guideline would be to warn the harvesters NOT to rake up the duff (not a usual activity for chanterelle picking, as a rule), not to pick the truly tiny chanterelles, and to leave the obviously over-the-hill chanterelles in the woods. By the way, we have found that the tiny pinhead primordia tend NOT to develop if the larger chanterelles associated with it have been picked. My suggestion in that case would be simply to take the entire cluster (this is when the fruitbodies are all connected in one big mass) when the larger chanterelles are harvested.

Lorelei

Correspondence 3:

Karen ,

Lorelei's answer is pretty complete, but now we are getting some preliminary DNA data that indicates there is quite a bit of breeding going on within the study. Only a few years' data have been analyzed so far, but it seems there is some variation, however slight. But we don't know yet whether it is from new spores contributing their genes or from mycelium already present in the soil. We hope to be able to determine that at some point.

Also, we are finding some populations will lie dormant for a few years then reactivate. There are normal up and down cycles, some short and some longer, then a quiescent period, then re-invigoration. We do not know the cause yet.

Another detail we are noticing is that in the harvest plots that are cut, often a cluster of new chanterelles will fruit, and can carefully be harvested a few at a time as they grow. If they are pulled, however, there are small ones that are developing at the base of the stem that are then lost. In the clusters, not all will develop fully, but often two or three others will develop quite fully. So we are starting to recommend cutting as a harvest method since more specimens usually develop. In the pull plots, another chanterelle will often appear where the first one was harvested, but much later in the season.

Hope this helps.

Judy

Correspondence 4:

Ahhhhh

This is why studies should be conducted for more than a few years. Judy's observations on the cut versus pulled chanterelles obviously negates my message of a half hour ago. This is very interesting news — so you may advise your harvesters to cut rather than pull.

Lorelei

Correspondence 5:

Dear all,

I read with great interest your discussion about chanterelle this morning.
I can add some information about the sporulation dynamics. 20 years ago my assistant studied the spore release of *Cantharellus lutescens*:

Kälin, I., F. Ayer. 1983. Sporenabwurf und Fruchtkörperentwicklung des Goldstieligen Pfifferlings (Cantharellus lutescens) im Zusammenhang mit Klimafaktoren. Mycologia Helvetica 2:67-88.

Summary:
The growth of 31 fruit bodies of *C. lutescens* and the number of spores released in consecutive two-day intervals were related to meteorological data (temperature, relative humidity, precipitation).
The fruit bodies investigated had an average life of 49 days (minimum 16, maximum 58 days), during which each released o total of between 250'000 and 100 million spores. Sporulation began immediately after the fruit bodies had appeared and was found to be strongly related to meteorological conditions, increasing in warm, dry weather and decreasing in wet, cold conditions.
Premature collection of small fruit bodies reduces spore production by a factor of 1'000 to 10'000 and may influence the reproductive potential of the fungus.

Kälin counted also some *Cantharellus cibarius* fruit bodies (not published):

the spore release is very similar, life span is still longer (up to 84 days). Considering these results I totally agree with the advice to harvest only chanterelles > 2 cm.

In Switzerland most cantons have introduced harvesting restrictions (the pressure is very high in this small country with a high population): in the first days of each month (1st -10th) harvesting of mushrooms is totally forbidden. This enables the mushrooms to release their spores (before they are picked).

I will inform you as soon as we have new knowledge on the influence of harvesting.

With best regards
Simon

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David Pilz, Lorelei Norvell, Eric Danell, Randy Molina. 2002 (in ed.)

Ecology and management of commercially harvested chanterelle mushrooms. Gen. Tech. Rep PNW-GTR- Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

CONTENTS: The international commerce of chanterelles, globally regarded as one of the best edible forest mushrooms, may well exceed several billion dollars annually. A variety of chanterelle species fruit plentifully in Pacific Northwest forests, and their abundance has spawned a significant commercial harvest industry during the last two decades. As chanterelles grow symbiotically with the roots of forest trees, managing the fungus for sustainable harvest also means managing forest habitats. This publication summarizes what is now known about chanterelles with an eye toward providing forest managers, policy makers, mushroom harvesters, and mushroom enthusiasts with accurate information for an informed debate about chanterelle management. The handbook begins by discussing chanterelles around the world to place the Pacific Northwest species and harvests in their historical, cultural, economic, and international context. The authors then examine the biology, ecology, chemistry, and nutrition of chanterelles and cover the recent declines in productivity reported in Europe and current efforts to cultivate chanterelles in plantations. The authors then shift their focus to chanterelles in the Pacific Northwest and describe local species, discuss management issues, and summarize current research. Finally, they consider future research and development that may help ensure a continued abundance of chanterelles in the forests.

Norvell, Lorelei. 1999.

Flash! Mushroom debate in Oregon senate makes headline news! **Inoculum** 50(4): 5.
CONTENTS: Report on the humorous legislative debate preceding approval of the Pacific Golden Chanterelle (*Cantharellus formosus)* as the official Oregon State mushroom. Cartoon.

Lorelei L. Norvell, Judy Roger. 1998.

The Oregon *Cantharellus* Study Project: Pacific Golden Chanterelle preliminary observations and productivity data (1986-1997). Abstract in **Inoculum** 49(2): 40.
ABSTRACT: *Cantharellus formosus* (the Pacific Golden Chanterelle) is the principal choice edible ectomycorrhizal chanterelle commercially harvested from Pacific Northwest (British Columbia, Washington, Oregon, and California) coastal forest. In 1986 the Oregon Mycological Society initiated North America's longest continuous investigation into the impact of harvesting on subsequent productivity. A total of ten individual plots (in three replicate blocks) were established in a 120 year old *Tsuga-Pseudotsuga* stand in the buffer zone of Portland's Bull Run watershed in Mt Hood National Forest. Within the plots 292 species of fungi (123 mycorrhizal, 106 terricolous saprophytes, 56 lignicolous saprophytes and parasites, 7 fungal parasites) have been recorded. Since 1986 volunteer researchers have tracked 5471 chanterelles (individually numbered, flagged, measured and mapped) every two weeks from July to December. Beginning in 1989 all chanterelles over 1 cm in diameter have been removed by cutting (3 plots) or pulling (3 plots), weighed before and after drying to determine biomass and retained for future molecular analysis; the remaining four non-harvest plots are monitored as controls. Nine years of harvesting data indicate that removal of chanterelles may slightly stimulate subsequent chanterelle productivity (measured both as numbers of basidiomes and as biomass) in the short term. A statistically significant positive correlation between mean summer temperatures and numbers of chanterelles is suggested, but there appears to be little to no correlation between productivity and harvesting method. Other observations include the relatively slow growth rate (e.g., expansion of the pileus diameter at a rate of 2-5 cm/month) and long life span with fruiting bodies observed *in situ* for as long as 90 days. Factors that may influence productivity include canopy cover, short and long term weather patterns, and the presence of coarse woody debris. The internationally recognized study demonstrates how collaboration between professionals and amateurs (who have together thus far generously donated nearly 5000 hours of labor) can contribute significant and valuable scientific knowledge.

Scott Redhead. Lorelei Norvell. Eric Danell. 1997.

Cantharellus formosus and the Pacific Golden Chanterelle harvest in western North America. **Mycotaxon** 65: 285-322.
CONTENTS: This is the first detailed account of the identity of the commonly harvested western chanterelle, which is here named the Pacific Golden Chanterelle. The type locality for the name *Cantharellus formosus* E.J.H. Corner (1966) on Vancouver Island, was located and visited to procure fresh specimens for DNA analysis. A description with illustrations is published. A new chanterelle, the Rainbow Chanterelle (*Cantharellus cibarius var. roseocanus* Redhead, Norvell & Danell) is described, illustrated, and compared to *C. formosus*. Documentation of harvesting is recorded. Photos, maps.

Lorelei Norvell. Judy Roger. Janet Lin dgren. Frank Kopecky. 1996.

Study 8: Oregon Cantharellus Study Project 1986-1996. IN David Pilz & Randy Molina, eds. **Managing fungal diversity and wild mushroom harvesting in forest ecosystems**. Gen. Tech. Rep. PNW-GTR-371 USDA-FS, PNW Research Station, Portland, Oregon. pp 69-72.
CONTENTS: This paper, based on Norvell's presentation at the 1994 Corvallis conference, presents the context, objectives, methods and rationale, unique considerations, current status, and references pertinent to the Oregon Mycological Society's long-term experimental study designed to assess the impact of sporocarp removal upon chanterelle abundance and biomass.

SA Redhead. LL Norvell. E Danell. 1996.

Is *Cantharellus formosus* being commercially harvested? Abstract in **Inoculum** 47(3): 30.
CONTENTS: *Cantharellus formosus* was described by EJH Corner in 1 966 from a collection made on Vancouver Island, British Columbia, Canada in 1938. Subsequent treatment of the species has been checkered. it has been listed both as a possibly rare, old-growth forest indicator species in Forest Ecosystem Management Team (FEMAT) reports, and as a commercially harvested chanterelle in western North America. In 1995 the type locality was pinpointed, fresh topotype specimens were obtained, and molecular analyses using RFLP data were conducted. Comparison of topotype specimens with commercially harvested chanterelles in Canada and the Pacific Northwest USA and chanterelles from the pioneering Oregon Mycological Society's Chanterelle Study Plots will be given in a status report on this research.

Lorelei L Norvell. 1995.

Loving the chanterelle to death? The ten-year Oregon chanterelle project. **McIlvainea** 12(1): 6-25.
CONTENTS: A fully referenced overview of the Oregon Mycological Society's ground-breaking study conducted entirely by volunteers, the first in North America to establish permanent experimental and control plots to compare the impact of sporocarp removal upon subsequent fruiting. Provides a background on possible causes for decline in mushroom

productivity in America and overseas (pollution, habitat destruction, over-harvesting), details the experiment site, project design and protocols, and offers the first preliminary conclusions inferred from three years baseline and six years of harvesting data. These data suggest: (i) no statistically significant correlation between sporocarp removal and productivity, (ii) an outcome not influenced by harvesting method (pulling versus cutting); (iii) a significantly positive correlation between chanterelle abundance and average summer temperature; and (iv) no correlation between chanterelle abundance and precipitation. The author also notes that the chanterelle being studied probably represents the endemic *Cantharellus formosus* and not *C. cibarius.* [Ten-year harvesting data now imply that chanterelle removal may stimulate future chanterelle abundance, see Norvell & Roger, 1998, above.]

Lorelei L Norvell, Frank Kopecky, Janet Lindgren, Judy Roger. 1995.

The Chanterelle *(Cantharellus cibarius)* -- A Peek at Productivity. *IN* **Proceedings: The Business and Science of Special Forest Products -- A Conference and Exposition January 26-27, 1994**. Chris Schnepf, ed. Western Forestry and Conservation Association, Portland, OR. pp. 117-128.

ABSTRACT: Since 1986 the Oregon Cantharellus Study Project team has been engaged in long-term research of the chanterelle, a commercially harvested edible mushroom associated with economically significant timber species in the Pacific Northwest. Eight years ago Oregon Mycological Society members established 10 plots in a 100 year old hemlock-Douglas-fir stand in the buffer zone of Mt Hood's Bull Run watershed to study whether harvesting chanterelles adversely affects later fruitings. All chanterelles have been numbered, flagged, measured, and mapped every 2 weeks throughout the growing season. Since 1989 all chanterelles over 1 cm in diameter have been removed from 6 of the 10 plots, either by cutting (3 plots) or by pulling (3 pots). No chanterelles have been removed from the 4 control plots. while data reveal a wide fluctuation of overall productivity -- indicated by biomass as well as numbers of fruiting bodies -- from year to year, harvesting data fail to show that picking chanterelles has an impact on the subsequent productivity over the short term. Factors that may influence productivity include canopy cover, short and long term weather patterns, and the presence of coarse woody debris.

LL Norvell. 1992.

Studying the effects of harvesting on chanterelle productivity in Oregon's Mt. Hood National Forest. *In* **Wild Mushroom Harvesting Discussion Session Minutes**. Edited by DeGeus, Redhead, Callan. Province of British Columbia, Ministry of Forests: Victoria, British Columbia. 9-15.

AND

Studying the effects of mushroom harvesting on chanterelle productivity in Oregon's Mt. Hood National Forest. *Abstract in* **Northwest Natural Sciences Annual Meeting Program**: p. 34.

CONTENTS: Both publications provide background on the harvesting controversy in western North America and give an overview of the site, experimental design and protocols followed by the Oregon *Cantharellus* Study Project now being conducted by Oregon Mycological Society volunteers. The ten-year study, now in its sixth year, will attempt to determine the impact of chanterelle removal upon the subsequent sporocarp abundance and biomass. Since 1986, new chanterelles have been flagged by numbered skewers and mapped by triangulation with the dimensions of each fruiting body recorded every two weeks through the fruiting season. Since 1989 six of the ten plots have been harvested with chanterelles removed by cutting (3 plots) or pulling (3 plots). Four plots (in which no chanterelle removal is permitted) serve as controls. Three years of harvesting data indicate that picking chanterelles does not have an adverse impact on subsequent chanterelle productivity over the short term.

Fungus-tree partnership provokes innovative study. **Western Forester** 37(2): 22.
CONTENTS: An overview of the purpose and methodology of the cooperative Oregon Mycological Society/USDA Forest Service/City of Portland "Oregon *Cantharellus* Study Project" which seeks to investigate the ecology of the chanterelle and the impact of mushroom harvesting on subsequent productivity.

L.L. Norvell. 1991.

A study on the effects of harvesting on chanterelle productivity in Mt. Hood National Forest, Oregon. Abstract in **MSA Newsletter** 42(l): 29.
ABSTRACT: The choice edible *Cantharellus cibarius*, ectomycorrhizal with various forest trees, is an economically significant secondary forest product. In 1986 the Oregon Mycological Society (helped by the USDA Forest Service) initiated a ten-year study on whether or not chanterelle harvesting would adversely affect productivity or the growth of the mycorrhizal partners. Ten study plots were established in a 100-year old hemlock-Douglas fir stand in the buffer zone of Mt Hood's Bull Run watershed. Since 1986, new chanterelles have been flagged by numbered skewers and mapped by triangulation with the dimensions of each fruiting body recorded every two weeks through the fruiting season. Since 1989 six of the ten plots have been harvested with chanterelles removed by cutting (3 plots) or pulling (3 plots). Four plots (in which no chanterelle removal is permitted) serve as controls. Three years of harvesting data indicate that picking chanterelles does not have an adverse impact on subsequent chanterelle productivity over the short term. Additional observations suggest that canopy closure, annual mean temperature, precipitation, and the presence of coarse woody debris may be more significant in the productivity of a given chanterelle site.

Lorelei Norvell. 1988.

Charting the Chanterelle (The Regular Column). **Mushroom, The Journal** 6(1): 19-21.
CONTENTS: An amusing account of the vicissitudes and joys of developing and conducting the ground-breaking Oregon *Cantharellus* Study Project on the impact of mushroom harvesting on subsequent mushroom fruiting. Cartoons.

APPENDIX B – Lichen and Bryophyte Collection Data

SPECIES	Site 1	Site 2	Site 3	Site 4	Site 5
MOSSES	(Wapawekka)	(Wapawekka)	(BERM)	(Bear River)	(Meeyomoot)
Ceratodon purpureus	·	■	·	·	·
Dicranum fuscescens	■	■	■	·	■
Dicranum polysetum	■	■	■	·	■
Dicranum scoparium	■	■	·	·	·
Oncophorus wahlenbergii	·	■	■	·	■
Pleurozium schreberi	■	■	■	·	■
Pohlia nutans	·	·	■	■	■
Polytrichum commune	·	·	·	·	■
Polytrichum juniperinum	·	·	■	·	·
Polytrichum piliferum	■	■	·	■	·
Ptilium crista-castrensis	■	■	·	·	·
	·	·	·	·	·
LIVERWORTS	·	·	·	·	·
Lepidoza reptans	·	·	·	■	·
Ptilidium pulcherrimum	■	■	■	·	·
	·	·	·	·	·
LICHENS	·	·	·	·	·
Baeomyces rufus	·	·	·	■	·
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Bryoria fuscescens	■	■	·	■	■
Bryoria lanestris	·	·	·	■	·
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Cetraria ericetorum	■	■	■	■	·
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Cladonia borealis	■	■	■	■	·
Cladonia botrytes	·	·	■	·	·
Cladonia cenotea	■	·	·	■	·
Cladonia chlorophaea	■	·	·	·	·

Cladonia coniocraea	·	·	■	·	·
Cladonia cornuta	■	■	·	■	■
Cladonia crispata	·	■	■	■	·
Cladonia cristatella	·	·	·	■	·
Cladonia deformis	■	·	·	·	·
Cladonia fimbrata	·	■	■	·	■
Cladonia gracilis	·	■	■	■	■
Cladonia multiformis	■	■	■	·	·
Cladonia phyllophora	■	■	■	·	·
Cladonia pyxidata	·	·	■	■	■
Cladonia sulphurina	·	·	■	·	·
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Cladonia verticillata	·	■	·	·	·
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Flavocetraria nivialis	■	·	·	·	■
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Imshaugia placorodia	■	■	·	■	·
Lecanora circumborealis	■	·	■	·	·
Lecanora pulicaris	·	·	·	■	■
Lecanora symmicta	·	■	·	·	·
Lecidella euphorea	·	·	■	■	·
Parmelia saxtilis	■	·	·	·	·
Parmelia sulcata	■	■	·	■	·
Parmeliopsis ambigua	■	·	■	■	■
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Peltigera didactyla	·	·	·	·	■
Peltigera malacea	·	■	■	■	■
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Stereocaulon alpinum	■	·	·	■	·
Tuckermannopsis americana	■	■	■	·	■
Usnea hirta	·	■	■	■	■
Usnea subfloridana	■	■	■	·	·
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Xylographa abietina	·	·	·	·	■

LEGEND

	Frequency of Occurrence
■	100% of plots
	80% of plots
	60% of plots
☒	Found in plot, but was not present in moss/lichen sample bag.

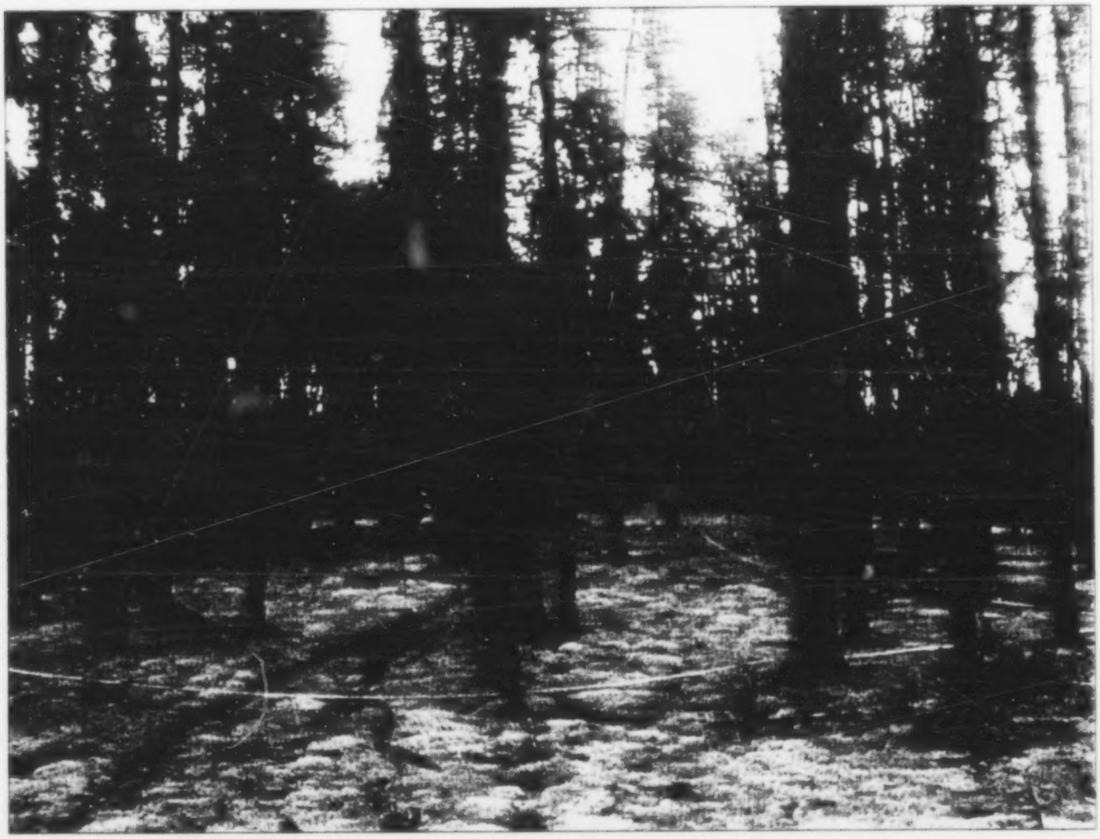
APPENDIX C – Vascular Plant Species List

Trees and Shrubs	**Scientific Name**	**Common Name**
PINUBAN	*Pinus banksiana*	Jack pine
VACCANG	*Vaccinium angustifolium*	Blueberry
VACCVIT	*Vaccinium vitis-idea*	Dry ground cranberry
ARCTUVA	*Arctostaphylos uva-usi*	Bearberry
POTETRI	*Potentilla tridentata*	Three-toothed cinquefoil
AMELALN	*Amelanchier alnifolia*	Saskatoon berry
Forbs & Graminoids		
ARALNUD	*Aralia nudicaulis*	Wild sarsaparilla
ANEMCAN	*Anemone canadensis*	Canada anemone
ANEMMUL	*Anemone multifida*	Cut-leaved anemone
CAMPROT	*Campanula rotundifolia*	Common harebell
HIERUMB	*Hieracium umbellata*	Narrow-leaved hawkweed
MAIACAN	*Maianthemum canadensis*	Two-leaved Solomon's seal
MELAMLIN	*Melampyrum lineare*	Cowwheat
SOLICAN	*Solidago canadensis*	Canada goldenrod
AGROSCA	*Agrostis scabra*	Rough hairgrass (Tickle grass)
ORZOPUN	*Oryzopsis pungens*	Northern rice grass

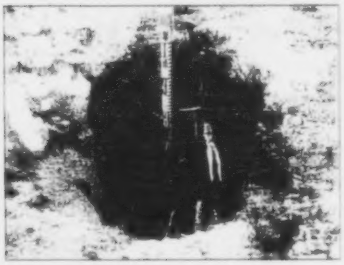
***Authority:** *Plants of the Western Boreal Forest and Aspen Parkland*
D. Johnson, L. Kershaw, A. MacKinnon, and J. Pojar. Lone Pine Publishing, 1995.

APPENDIX D – Plot Photo plates

SITE 1 – Wapawekka



Ecosite: *a – lichen*
Ecosite Phase: *a1 – lichen jP*
Plant Community Type: a1.2 – *jP/blueberry/lichen*



Parent Material: medium to fine sandy, glaciofluvial

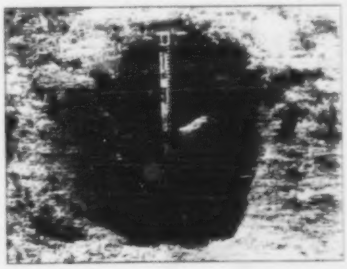
Soil Classification: Eluviated Eutric Brunisol

SITE 2 – Wapawekka

Ecosite: *a – lichen*

Ecosite Phase: *a1 – lichen jP*

Plant Community Type: a1.1 – *jP/bearberry/lichen*



Parent Material: fine sandy, fluvial-lacustrine

Soil Classification: Eluviated Eutric Brunisol

SITE 3 – BERM

Ecosite: *a – lichen*
Ecosite Phase: *a1 – lichen jP*
Plant Community Type: - no fit -

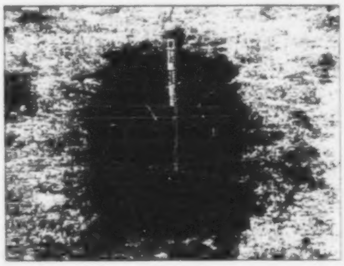
- no soil photo available -

Parent Material: fine sandy, fluvial-lacustrine

Soil Classification: Eluviated Eutric Brunisol

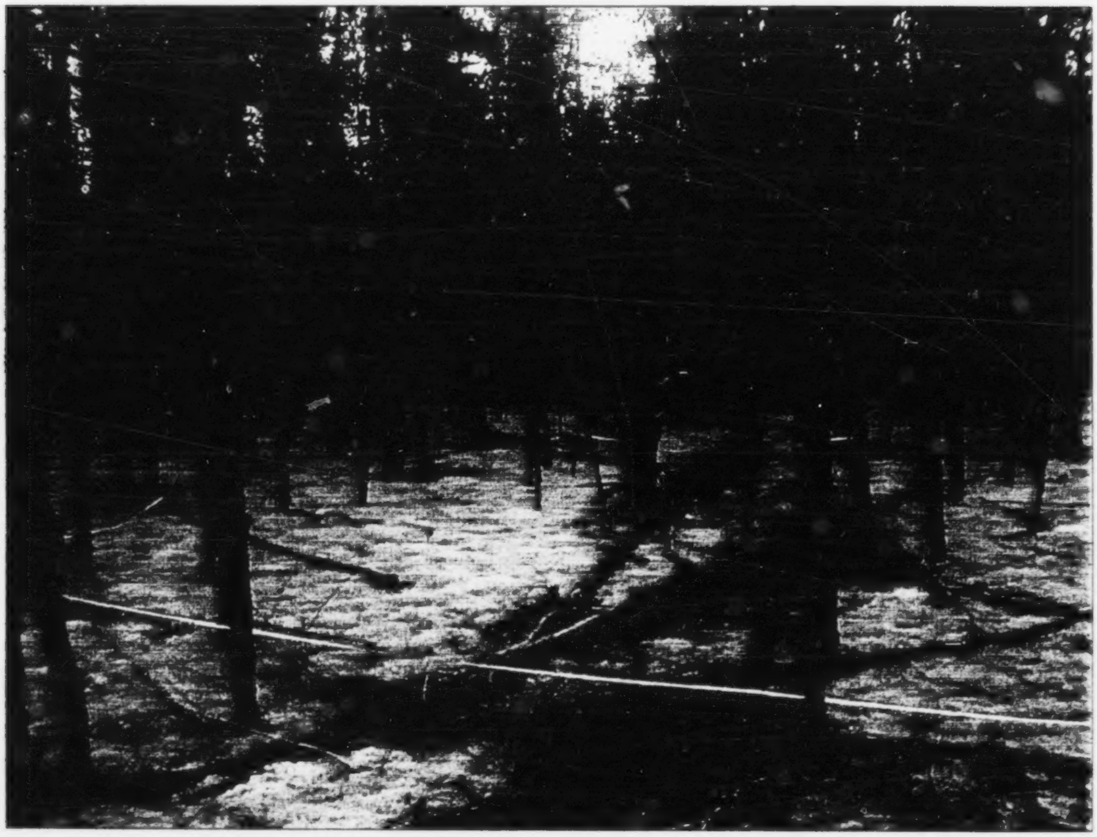
SITE 4 – Bear River

Ecosite: *a – lichen*
Ecosite Phase: *a1 – lichen jP*
Plant Community Type: a1.1 – *jP/bearberry/lichen*

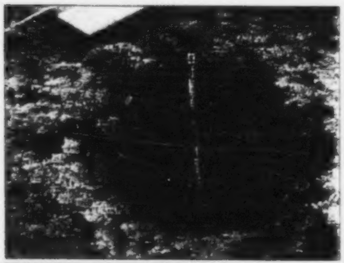


Parent Material: medium to fine sandy, glaciofluvial
Soil Classification: Eluviated Eutric Brunisol

SITE 5 – Meeyomoot

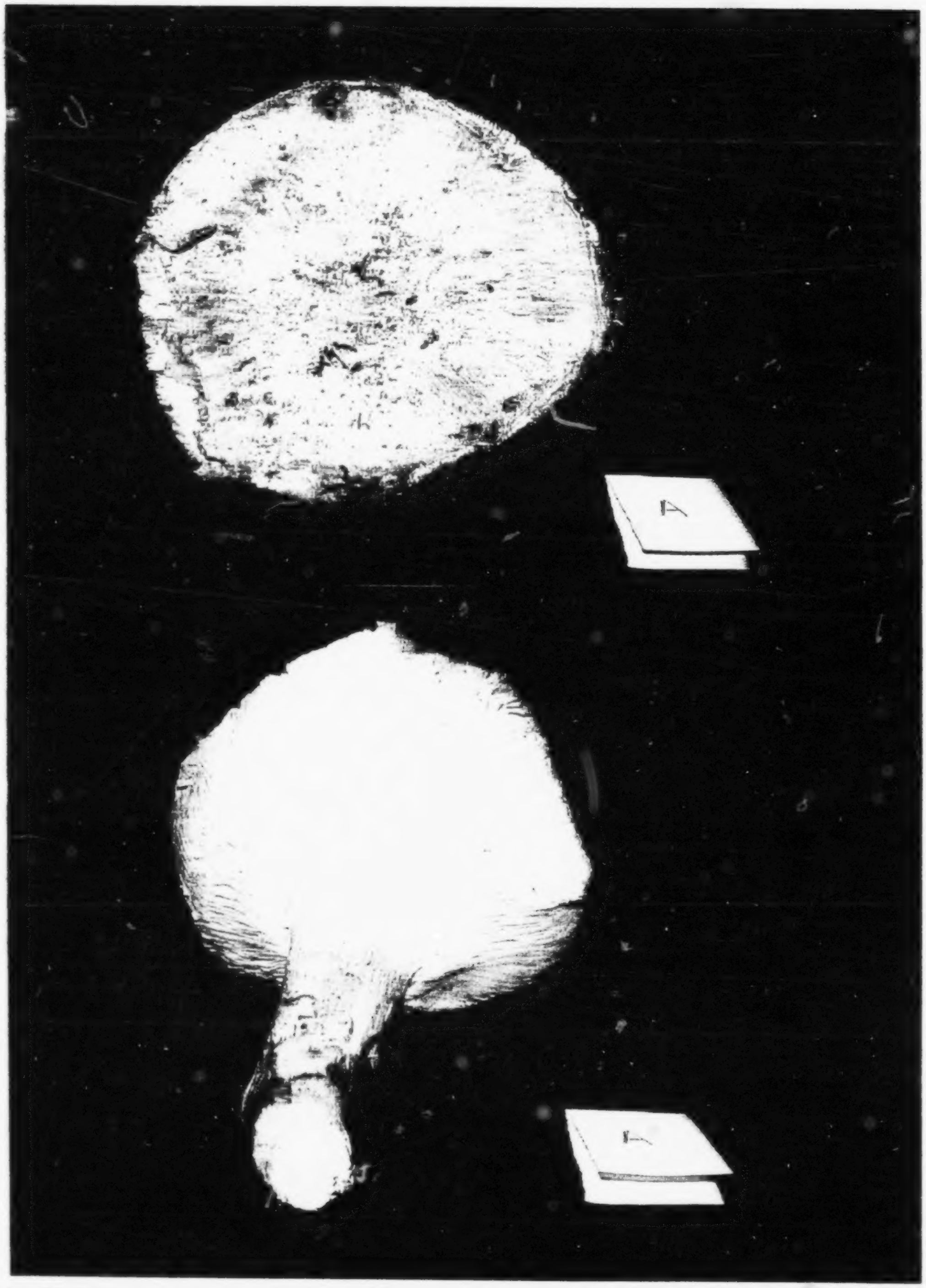


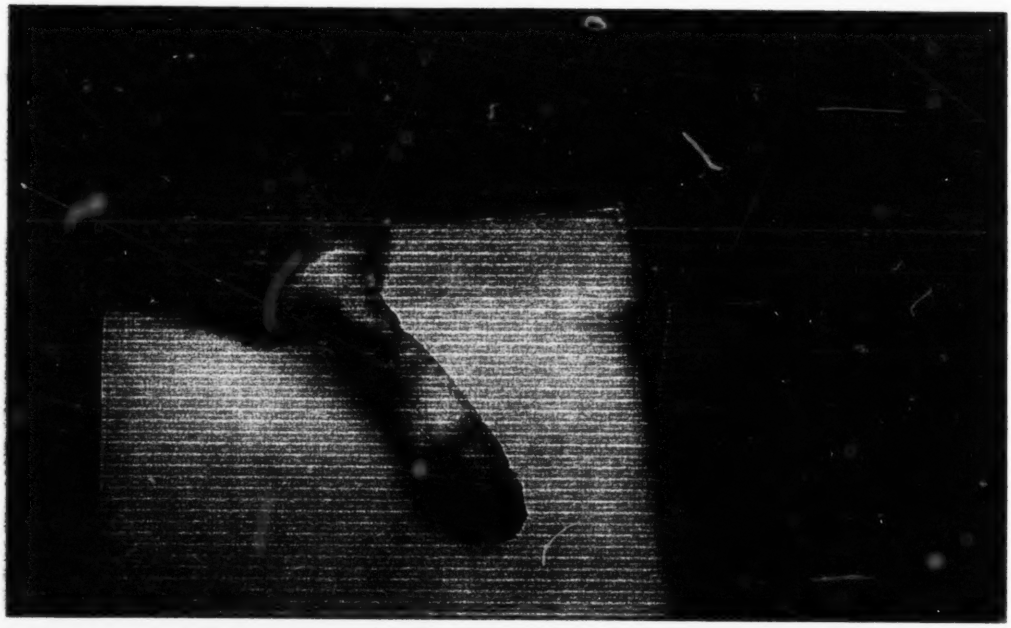
Ecosite: *a – lichen*
Ecosite Phase: *a1 – lichen jP*
Plant Community Type: a1.1 – *jP/bearberry/lichen*

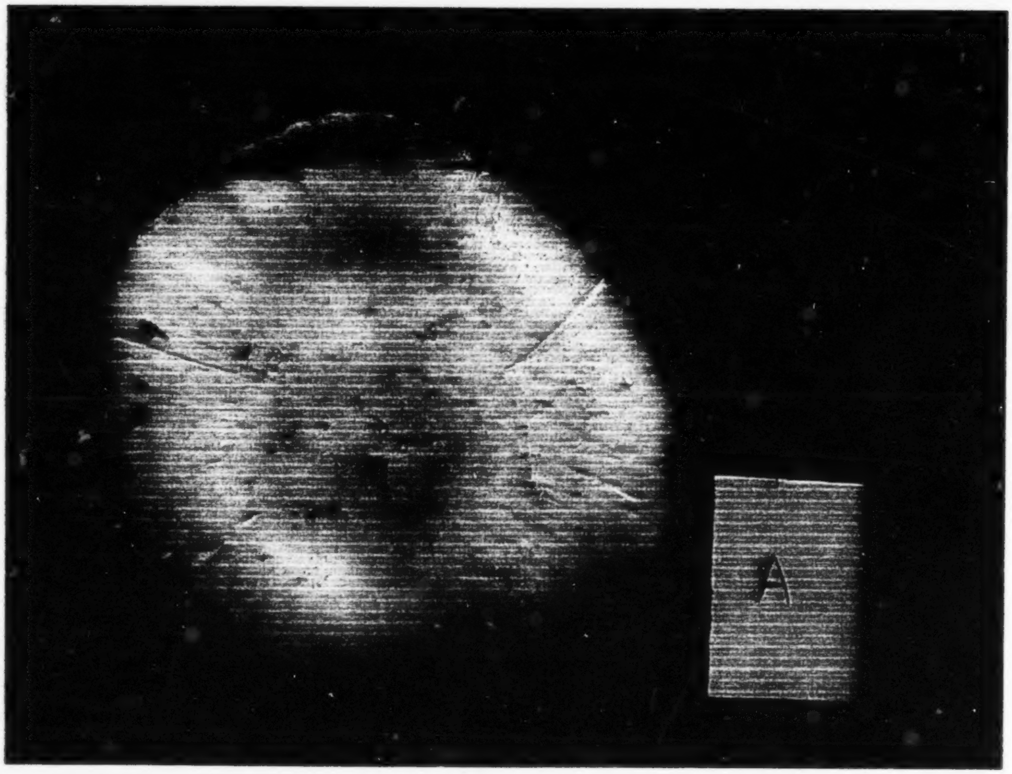


Parent Material: fine sandy. fluvial-lacustrine
Soil Classification: Eluviated Eutric Brunisol

APPENDIX E –Pine Mushroom Under Remay Covers






A

APPENDIX F

Table 4.9 Mushroom Inventory Plots 2002

#	UTM NAD 27 13U	STAND #	SPECIES	CROWN CLOSURE	DECADE OF ORIGIN	TREE HEIGHT	D.B.H.	TREE AGE	MUSHROOM SPECIES PRESENT 2002, 2003	Stand Area In Hectares
1	480103 6073548	610	JP	D	1940	12M	12cm	74yr	Chants yes Pines nil	14.78
2	480287 6073705	607	JP	C	1880	16.4M	25cm	76yr	Chants yes Pines nil	55.03
3	480380 6073874	609	JP	D	1930	11.85 M	12.2 cm	54yr	Chants nil Pines nil	9.92
4	480378 6074099	596	JP	B	1880	18.8M	20.4 cm	117yr	Chants nil Pines nil	33.69
5	480391 6074943	591	JP	A	1940	10.0M	10.3 cm	41yr	Chants nil Pines nil	15.58
6	480114 6074881	595	JP	D	1940	10.65 M	12.5 cm	39yr	Chants nil Pines yes	9.50
7	480471 6074578	606	JP	A	1880	12.6M	17.5 cm	53yr	Chants nil Pines nil	21.03
8	480303 6073469	611	JP	D	1940	14.4M	16.2 cm	66yr	Chants nil Pines nil	14.32
9	480503 6075385	322	JP	D	1940	13.5M	12.3 cm	58yr	Chants yes Pines nil	14.81
10	480506 6075873	320	JP	D	1940	13.35 M	10.2 cm	65yr	Chants yes Pines nil	50.16
11	480555 6076593	315	JP BS	B	1940	13.65 M	13.2 cm	57yr	Chants yes Pines nil	21.85
12	481642 6075282	632	JP BS	D	1940	12.48 M	10.3 cm	59yr	Chants yes Pines nil	18.35
13	481781 6075276	633	JP BS	B	1940	14.4M	13cm	65yr	Chants yes Pines nil	4.56
14	482098 6075273	651	JP BS	C	1940	8.55M	11cm	40yr	Chants yes Pines nil	20.54
15	483060 6075551	653	JP BS	D	1940	7.65M	9.8cm	48yr	Chants nil Pines nil	8.35
16	483706 6075955	416	JP BS	D	1940	11.25 M	14.1 cm	58yr	Chants nil Pines nil	12.12
17	463211 6058266	122	JP	C	1980	6.6M	8.8cm	16yr	Chants nil grass Pines nil	174.48

18	463475 6057453	282	JP	C	1980	7.8M	10.2 cm	17yr	Chants nil tA grass Pines nil	28.83
19	465071 6056595	325	JP	C	1980	8.1M	13.7 cm	31yr	Chants nil grass Pines nil	36.44
20	465071 6056501	329	JP	C	1980	6.9M	10.1 cm	18yr	Chants nil grass Pines nil	8.95
21	466412 6055648	554	JP BS	C	1940	9.45M	8.7cm	53yr	Chants nil Pines nil	7.06
22	466540 6055716	398	JP	B	1980	3.75M	4.5cm	25yr	Chants nil Pines nil	24.48
23	466327 6056366	364	JP	B	1980	6.9M	11.5 cm	19yr	Chants yes Pines yes	7.66
24	466394 6056301	366	JP BS	B	1940	9.75M	10.5 cm	50yr	Chants yes Pines nil	5.62
25	466628 6053581	810	JP BS	A	1980	14.8M	20.7 cm	95yr	Chants nil Pines nil	4.61
26	466774 6053038	813	JP BS	B	1980	20M	26.4 cm	110yr	Chants nil Pines nil	3.91
27	464145 6056659	332	JP BS	C	1980	4.95M	4.0cm	29yr	Chants nil lab tea Pines nil	2.44
28	564624 6049869	767	JP	C.O.	1986	cut	burnt	1995	Chants nil Pines nil	50.73
29	564890 6049500	776	JP	C.O.	1986	cut	burnt	1995	Chants nil Pines nil	16.66
30	564835 6049799	771	JP	C.O.	1986	cut	burnt	1995	Chants nil Pines nil	12.57
31	564928 6049623	778	JP BS	D	1920	cut	burnt	1995	Chants nil Pines nil	2.18
32	565586 6048742	105	JP	D	1920	burnt		1995	Chants nil Pines nil	10.52
33	566083 6048296	108	JP BS	D	1920	burnt		1995	Chants nil Pines nil	12.22
34	565859 6048332	95	JP BS	D	1920	burnt		1995	Chants nil Pines nil	8.52
35	566220 6048019	253	JP BS	D	1920	burnt		1995	Chants nil Pines nil	10.94
36	566345 6048053	111	JP BS	D	1920	burnt		1995	Chants nil Pines nil	7.08
37	567186 6047280	285	JP	C	1920	burnt		1995	Chants nil Pines nil	5.93

38	473253 6047827	114	JP BS	A	1910	15.3M	19cm		Chants nil Pines nil	5.20
39	472992 6048089	113	JP BS	D	1940	10.35 M	7.6c m	35yr	Chants nil Pines yes	5.48
40	562766 6052805	442	JP	B	1850	11.1M	14.8 cm	59yr burnt	Chants yes Pines nil	7.99
41	563037 6052347	443	JP	B	1850	12.6M	16.2 cm	53yr burnt	Chants yes Pines nil	25.16
42	561451 6053918	370	JP BS	B	1850	19M	23.7 cm	71yr	Chants yes Pines yes	11.13
43	477290 6033847	627	JP	B	1940	14.7M	19.3 cm	52yr	Chants yes Pines nil	37.99
44	477525 6033847	628	JP	C	1940	13.8M	14.2 cm	51yr	Chants nil Pines nil	13.68
45	563037 6052066	429	JP BS	B	1850	burnt		1995	Chants nil Pines nil	53.22
46	562178 6053559	384	JP BS	C	1890	8.85M	12cm	53yr burnt	Chants yes Pines nil	12.31
47	561308 6054319	710	JP BS	C	1890	16.5M	18cm	75yr	Chants nil Pines yes	15.64
48	561711 6053998	378A	JP	B	1890	15.6M	26.5 cm	112yr	Chants yes Pines nil	1.97
49	572262 6041711	454	JP	A	1970	burnt		1995	Chants nil Pines nil	11.43
50	571210 6043050	362	JP	D	1970	burnt		1995	Chants nil Pines nil	124.32
51	571319 6043158	378	JP	B	1970	6.3M	5.4c m	32yr	Chants yes Pines yes	13.18
52	571183 6043361	374	JP BS	C	1970	burnt		1995	Chants nil Pines nil	0.29
53	570728 6044088	365	JP BS	D	1970	burnt		1995	Chants nil Pines nil	43.75
54	570404 6044383	238	JP BS	C	1970	burnt		1995	Chants nil Pines nil	63.18
55	570225 6044381	356	JP	A	1970	burnt		1995	Chants nil Pines nil	6.25
56	570827 6042603	430	JP	C	1970	burnt		1995	Chants nil Pines nil	14.3
57	571829 6043346	372	JP BS	A	1970	burnt		1995	Chants nil Pines nil	33.89
58	571655 6043999	370	JP BS	A	1970	burnt		1995	Chants nil Pines nil	19.44
59	4779190 6033337	823	JPBS	D	1940	18.6M	21.7 cm	69yr	Chants nil Pines yes	12.19

60	477897 6032988	863	JP BS	D	1940				Chants nil Pines yes	15.81
61	574522 6040633	609	JP BS	D	1910	burnt		1995	Chants nil Pines nil	7.6
62	574204 6041066	603	JP BS	D	1910	17.2M	17.2 cm	71yr	Chants nil Pines yes	5.76
63	573116 6041208	479	JP	A	1970	burnt		1995	Chants nil Pines nil	7.23
64	550590 6050032	20	JP	B	1940	10.5M	16.5 cm	55yr	Chants yes Pines nil	8.26
65	550162 6049534	4	JP	B	1940	11.85M	11cm	52yr	Chants yes Pines yes	16.19
66	550135 6048797	16	JP	B	1940	15.3M	15.2 cm	59yr	Chants yes Pines nil	11.45
67	550013 6048606	8	JP	B	1940	14.1M	13.5 cm	53yr	Chants yes Pines yes	7.11
68	550736 6050117	22	JP	B	1940	12.45M	12.3 cm	53yr	Chants yes Pines yes	124.61
69	561243 6054085	269	JP BS	D	1920	12M	12.7 cm	60yr	Chants yes Pines nil	25.58
70	468150 6068264	284	JP BS	B	1980	3.08M	3.1cm	28yr	Chants nil Pines nil	12.97
71	550432 60432470	279	JP BS	C	1890	16.8M	26.4 cm	66yr	Chants nil Pines yes	9.42
72	470290 6046363	235	JP	D	1940	11.54M	10cm	44yr	Chants yes Pines yes	68.00
73	476230 6075316	631	JP	D	1930	11.5M	11cm	68yr	Chants yes Pines yes	14.76
74	468955 6048356	192	JP	C	1940	14.4M	15.5 cm	56yr	Chants yes Pines nil	8.78
75	474202 6044670	495	JP	C	1940	13.5M	17.6 cm	98yr	Chants nil Pines nil	11.32
76	473580 6043533	647	JP BS	C	1910	19M	31,3 cm	101yr	Chants nil Pines nil	5.68
77	470591 6044740	412	JP	C	1940	19.98M	13.6 cm	51yr	Chants yes Pines nil	2.74
78	463085 6060280	1047	O. P.jp	N/A	1980	9.3M	9.8cm	27yr	Chants yes Pines nil	19.66
79	476865 6034138	611	JPBS	B	1940	13.0M	12.3 cm	51yr	Chant yes Pine yes	14.72
80	470689 6044767	414	JP	D	1940	8.4M	9.5 cm	56yr Mistletoe	Chant yes Pine nil	34.88

81	491916 6075510	591	JPBS	B	1940	9.45M	11.5 cm	45yr	Chant yes Pine Nil	6.7
82	492903 6074502	594	JPBS	C	1940	14.85M	15.1 cm	52yr	Chant yes Pine nil	12.96
83	4923361 6074672	593	JP	A	1940	11.4M	16.8 cm	47yr	Chant yes Pine yes	6.1
84	492083 6074414	620	JP	C	1940	12.9M	16.2 cm	60yr	Chant nil Pine nil	7.3
85	476632 6074682	704	JP	C	1980	7.5M	8.1cm	21yr	Chant yes Pine yes	103.4
86	503609 6081296	1027	JP	D	1940	15.75M	15.8 cm	63yr	Chant nil Pine nil	14.6
87	503872 6081403	1029	JP	B	1940	7.8M	9.5cm	45yr Mistletoe	Chant yes Pine nil	6.2
88	503944 6081119	1030	JP	D	1940	15.2M	16cm	70yr	Chant yes Pine yes	2.0
89	476210 6074171	691	JP	C	1980	7.2M	9.8cm	18yr	Chant yes Pine nil	34.5
90	477114 6074621	730	JP	B	1930	7.65M	11.3 cm	65yr Mistletoe	Chant nil Pine nil	4.8
91	475891 6074885	652	JP	D	1930	6.9M	8.8cm	23yr Mistletoe	Chant yes Pine nil	38.6
92	475912 6074643	674	JP	D	1980	4.34M	3.5cm	22yr	Chant yes Pine yes	19.3
93	475484 6074426	668	JP	D	1930		10.0 cm	62yr Mistletoe	Chant yes Pine nil	15.0
94	477068 6074485	707	JP	C	1980	7.0M	6.8cm	18yr	Chant nil Pine nil	169.3
95	504342 6081914	811	JP	C	1910	22.4M	22cm	105yr Mistletoe	Chant yes Pine nil	8.6
96	503305 6081066	1024	JPBS	C	1870	15.5M	12.3 cm	66yr	Chant yes Pine yes	8.7
97	503774 6081066	1031	JP	B	1940	16.0M	7cm	53yr	Chant yes Pine yes	5.40
98	504139 6081692	807	JP	C	1890	16.4M	18.6 cm	58yr Mistletoe	Chant yes Pine nil	4.7
99	503019 6080549	1020	JPBS	D	1887	14.25M	13.5 cm	53yr Mistlet	Chant yes Pine yes	10.0

								oe		
100	572514 6039380	16	O.P.(jp)	D	1970	5.0M	6.0cm	32yr	Chant Nil Pine Nil	175.9
101	444304 6104389	882	C.O.	C	1980	5.6M	6cm	18yr	Chant y Pine y	7.6
102	444874 6103863	901	C.O.	B	1980	5.3M	6.6cm	16yr	Chant Nil Pine Nil	20.4
103	441518 6105877	809	C.O.	B	1982	6M	6.9cm	20yr Grass	Chant Nil Pine Nil	37.2
104	443102 6105176	791	JPBS	D	1930	17M	21cm	83yr G. Moss	Chant Nil Pine Nil	8.7
105	443102 6105176	833	JPBS	D actually (A)	1920	11M	19.1 cm	80yr Mistletoe	Chant Nil Pine Nil	8.3
106	444750 6103748	909	JPBS C.O.	B	1880	6.9M	7.5cm	19yr	Chant Nil Pine Nil	7.0
107	445438 6103291	941	JP	B	1880	19.2M	22.6 cm	112 yr G Moss	Chant Nil Pine Nil	1.4
108	444372 6104117	870	C.O.	C	1980	6.1M	8.5cm	16yr	Chant Nil Pine Nil	23.6

Table 4.4 Occurrences of Chanterelle and Pine Mushrooms 2003

Waypoint List

Map Name : E1350608.tif
Map File : C:\OziExplorer\Maps\e1350608.map

Datum : NAD27 Canada

Waypoint File : C:\OziExplorer\Maps\Data\2003 Mushroom Inventory.wpt

9/7/2003 3:47:12 PM

Num	Name	Zone	Easting	Northing	Alt(ft)	Description
1	#192	13U	468955	6048356	1611	Chant
2	#412	13U	470591	6044740	1649	Chant
3	#414	13U	470689	6044767	1640	Chant
4	#591	13U	491916	6075510	1338	NO
5	#594	13U	492903	6074502	1418	Chant
6	#593	13U	492301	6074672	1372	NO
7	#620	13U	492083	6074414	1366	NO
8	#554	13U	466412	6055648		NO
9	#398	13U	466540	6055716		NO
10	#364	13U	466327	6056366		NO
11	#366	13U	466394	6056301		Chant
12	#810	13U	468628	6053581		NO
13	#813	13U	466774	6053038		NO
14	#647	13U	473580	6043533	1640	No
15	#809	13U	441518	6105877		No
16	#882	13U	444304	6104389		No
17	#909	13U	444750	6103748		N0
18	#941	13U	445438	6103291		No
19	#901	13U	444874	6103863		No
20	#870	13U	444372	6104117		No
21	#791	13U	441423	6106145	1300	No
22	#833	13U	443102	6105176	1282	No
23	#1047	13U	463085	6060280		Chant S10Bjp
24	#122	13U	463211	6058266		jNo
25	#282	13U	463475	6057453		No
26	#325	13U	465071	6058595		No
27	#329	13U	465071	6056501		No
28	#332	13U	464145	6056659		No
29	#809	13U	441518	6105877		No
30	#882	13U	444304	6104389		No
31	#909	13U	444750	6103748		No
32	#941	13U	445438	6103291		No
33	#901	13U	444874	6103863		No
34	#870	13U	444372	6104117		No
35	#791	13U	441423	6106145	1300	No
36	#833	13U	443102	6105176	1282	No
37	-811	13U	504342	6081914	0	Chantreelle
38	307	13U	530777	6084698	1277	S20B jpbs Chant actual Open Productive windfall
39	#1027	13U	503609	6081296	0	NO
40	#1029	13U	503872	6081403	0	Chant
41	#1030	13U	503944	6081119	0	Chant
42	#1024	13U	503305	6080793		Chant
43	#1031	13U	503774	6081066		Chant
44	#653	13U	483060	6075551		Chant
45	#416	13U	483706	6075955		No
46	#610	13U	480103	6073548		Chant

/aypoint List continued .....

Num	Name	Zone	Easting	Northing	Alt(ft)	Description
47	#607	13U	480287	6073705		Chant
48	#609	13U	480380	6073874		No
49	#596	13U	480378	6074099		Chant
50	#591	13U	480391	6074943		Chant
51	#595	13U	480114	6074881		Chants
52	#606	13U	480471	6074578		Chant C.O. S10A jp
53	#611A	13U	480303	6073469		No
54	#322	13U	480503	6075385		Chant
55	#320	13U	480506	6075873		Chant
56	#315	13U	480555	6076593		Chant
57	#632	13U	481642	6075282		No
58	#633	13U	481781	6075276		Chant
59	.#651	13U	482098	6075273		Chant
60	#653	13U	483060	6075551		Chant
61	#416	13U	483706	6075955		No
62	#631	13U	476230	6075316		Chant
63	#704	13U	476632	6074682		Chant
64	#691	13U	476210	6074171		No
65	#730	13U	477114	6074621		Chant C.O. S5A jp
66	#652	13U	475891	6074885		Chant
67	#707	13U	477068	6074485		No
68	#674	13U	475912	6074643		No
69	#668	13U	475484	6074426		Chant
70	371	13U	571692	6043468	1197	
71	#807	13U	504139	6081692		Chantrelle
72	#710	13U	561308	6054319		Chant
73	#378A	13U	561711	6053996		Chant
74	#20	13U	550590	6050032		Chant
75	#4	13U	550162	6049534		Chant
76	#22	13U	550736	6050117		Chant
77	#269	13U	561243	6054085	1463	Chant & PINE
78	#442	13U	562766	6052805		Chant B.O
79	#443	13U	563037	6052347		Chant BO
80	#429	13U	563037	6052066		Chant BO
81	#384	13U	562178	6053559		Chant BO
82	#710	13U	561308	6054319		Chant
83	#378A	13U	561711	6053998		Chant
84	#767	13U	564624	6049869		NO
85	#776	13U	564890	6049500		No
86	#771	13U	564835	6049799		No
87	#778	13U	564928	6049623		Chant
88	#105	13U	565586	6048742		No
89	#442	13U	562766	6052805		Chant
90	#443	13U	563037	6052347		Chant
91	#429	13U	563037	6052066		Chant
92	#384	13U	562178	6053559		Chant
93	#710	13U	561308	6054319		Chant
94	#378A	13U	561711	6053998		Chant
95	797	13U	504344	6082770		S20b jp 1940 Chant(22cm 63yr 15M
96	798	13U	504371	6082646		S10B jp 1940 Chant,Pines,12cm 11.2M 57yr
97	799	13U	504304	6082590		S10D jp 1940 ChantPine 13cm 61yr 13.5M
98	1033	13U	503802	6080903		S10C jpbs 1940 (chant 15cm 64yr 13.2M)
99	1034	13U	503658	6080617		S20C jpbs 1890 Chant Missletoe S20B 21cm 19.8M 126yr
100	1035	13U	503631	6080463		S10D jp 1940 Chant missletoe 13cm 61yr 12.6M
101	1038	13U	504172	6080825		S20C jp 1890(Chants,missletoeS20A32cm90yr19.5M)
102	408	13U	506404	6086248		S20B jpbs 1910(MissletoeS20A jp 26cm17M98yrNo)

Waypoint List continued .....

Num	Name	Zone	Easting	Northing	Alt(ft)	Description
103	411	13U	506279	6085951		S20D jpbs 1910S20B Ws (Ws 32cm108yr21M)No
104	413	13U	506660	6086164		S20c jp 1910 Chant(Missletoe21cm108yr19M
105	611	13U	476865	6034138	1592	Chant
106	-627	13U	477290	6033847	1581	No
107	-628	13U	477525	6033847	1592	No
108	-823	13U	477910	6033337	1568	No
109	-863	13U	477897	6032988	1598	No

Map Feature Waypoints